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ENGINEERING CASE LIBRARY

MANUFACTURING PROCESSES

SHORT CASES I

Prepared in the Department of Mechanical Engineering, University of British Columbia by R. E. Boston. Printed with permission in the Design Division, Department of Mechanical Engineering, Stanford University, Stanford, California, with support from the National Science Foundation.

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ACME DYERS LTD.

Acme Dyers were wholesale dyers of woolen and cotton cloth. Their equipment consisted of 7 dye kettles, 5 washing machines, and 2 dryers. All these machines used large quantities of steam and each machine required an electric motor of at least 7 1/2 hp. In order to take advantage of their high demand for steam and electricity the company decided to generate their own power from high pressure steam and utilize the resultant low pressure steam for heating and process work.

The company was able to buy a second-hand vertical steam engine with direct coupled generator at a reasonable price. A machinery mover was contracted to load the unit onto trucks for delivery to the dye works. Unloading at the plant, a rigger underestimated the weight of the flywheel and a sling chain broke, dropping the flywheel. The rim was cracked in three places and two spokes were broken. This necessitated the replacement of the entire flywheel.

EXHIBIT I

Engine and Generator Data

Steam Engine	- 50 Bhp
Generator	- 33 kw
Speed	- 230 rpm
Exciter	- 5 hp (belt driven from flywheel)

The maintenance supervisor of Acme Dyers was given the job of getting a new flywheel made. He knew that the local foundry had two cupolas of 3 tons each and that they could be overloaded by 50%. The foundry had a travelling crane of 5 tons capacity.

EXHIBIT II

Flywheel Data

Outside diameter	8' 0"
Rim thickness	8"
Rim width	1' 4"
Hub diameter	1' 2"
Bore	8"
Length through bore	1' 10"
Spokes	6
Spoke cross-section	8 sq. in.
Material	Cast Iron

QUESTION

How would this flywheel be made and could the local foundry do the job satisfactorily?

ORNAMENTAL ALUMINUM LIMITED

A new member of the production department was given the job of scheduling the cast aluminum pole holder as shown in Figure 1.

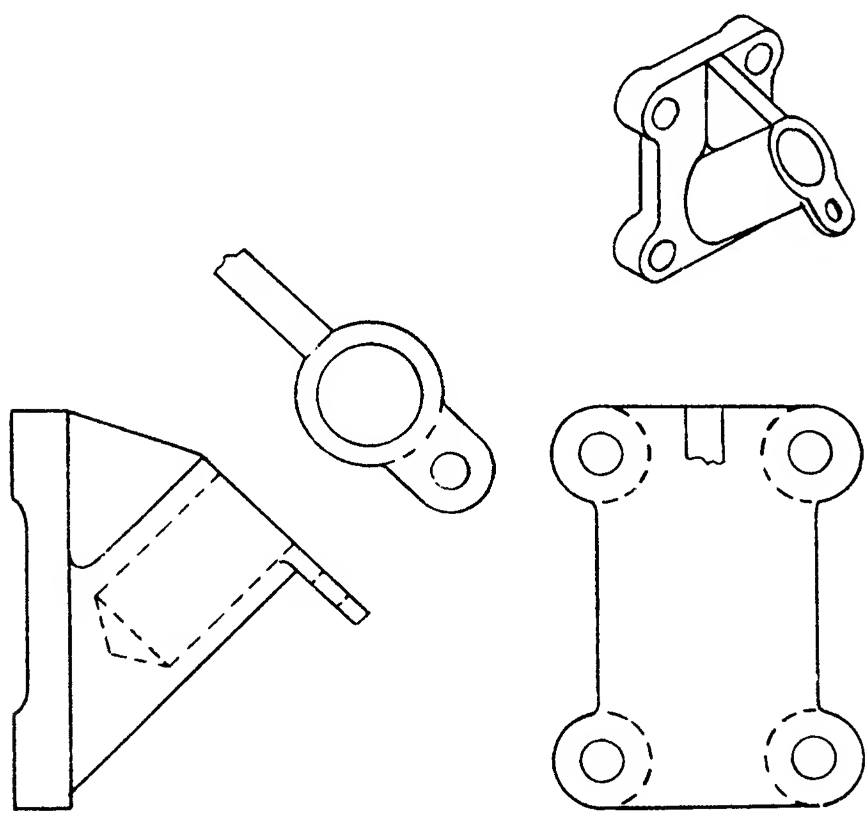
The shape of the object did not seem to allow for easy molding so he sketched a mold for the pole holder. This satisfied him that molds could be made. He then dispatched his sketch to the pattern making department.

His next problem was to decide on the type of mold and molding process. He was particularly concerned with this because the order was marked rush and a good surface finish was very important.

QUESTION: What would the mold look like and how would it be made? Label all parts.

FIGURE I

Pole Holder - cast aluminum



Scale - 1/2 full size

THE DOMINION ELECTRICAL EQUIPMENT CO.

This company is a very large manufacturer of all kinds of electrical equipment. Their line of products includes all types of household electrical appliances, all sizes of electrical motors and transformers as well as lamp bulbs and lighting fixtures.

EXHIBIT I

Figures from the financial report of the Dominion Electrical Equipment Co. for the year ending December 1, 1953

Total Assets	$111,402,000.
Working Capital	32,000,000.
Total Sales	205,000,000.
Cost of Sales	181,000,000.

In the past the company has experienced great difficulty in obtaining quality castings in sufficient quantity to keep its production lines continuously supplied. When iron was in short supply, foundries were inclined to allocate their production in proportion to past sales among all their customers. Similarly, if a foundry has orders on hand to meet all its capacity, Dominion Electrical Equipment Co. could not place a large order for castings and expect immediate delivery. It had also been observed that busy foundries were more anxious to produce castings than to see that each was of a high quality. As a result of all these difficulties, Dominion Electrical executives were considering setting up their own foundry to make all their own castings.

To determine the volume of business that could be expected, old purchase orders were examined. The average number of cast iron castings purchased per year are shown below. These castings on the average cost 10 cents/lb. and yielded the foundry concerned a profit of 3/4 cents/lb.

EXHIBIT II

Purchases of C.I. castings/year

Large castings - 1/2 ton to 10 tons	-	2000 tons/year
Medium castings - 10 lbs to 1000 lbs	-	7360 tons/year
Small castings - up to 10 lbs	-	1920 tons/year

For complete laboratory analysis of castings and sand it was felt that two laboratory technicians would be required to do nothing but testing. In addition, one man could spend all his time designing castings which could be easily poured to give a sound object of high quality.

When molding on a machine, one man can consistently turn out 60 medium size moulds/hour complete with cope drag and cores. Straight bench molding rates would be approximately one third of this. If a sand-slinger was used, a five foot square box could be filled in about three minutes.

So far as sand requirements are concerned, it is a rough rule that for every ton of castings, two ton of sand is required. Of each ton of sand used in moulding, 4 parts of old reclaimed sand could be used to 1 part of new sand. This would replace all losses and burnt sand. In most foundries only one man is required batching sand to keep the moulders supplied.

A hand operated core making machine is available for $130. It can be operated by an unskilled person and makes stock cores in increments of 1/8" up to 4" in diameter. The same unit motorized is worth $375. But for cores of about 20 cu.in., a bench model core blower is available for $175. The next size of core blower will make cores up to 4 cu.ft. and costs $4500.

EXHIBIT III

Weight and Sizes of Moulds

Size of Mould	Size of Casting	Weight of Sand
12" x 12" x 10" high	10-15 lbs. C.I.	20 lbs.
24" x 24" x 12" high	20-30 lbs. C.I.	60 lbs.
60" x 60" x 18" high	1000 lbs. C.I.	2000 lbs.

EXHIBIT IV

Cost of Foundry Supplies and Machines

Silica sand - $16/ton - in carload lots of 50 tons	
Sand testing equipment for testing permeability) moisture) strength) hardness)	$500 complete
Moisture tester only	$125 - hand size CaC tester
Sand conditioning,) reclaiming unit, and) conveying equipment)	$13,000 complete - capacity 25 ton/hour
Sand conditioner	$675 portable - capacity 8 tons/hour
Core oven (tray type)	$175 - 100 cu.ft. complete with burners
	$75 - 30 cu.ft. complete with burners

Snap flasks		
12" x 12" x 10" high	$70 each in wood	
	$135 each in aluminum	
24" x 24" x 12" high	$100 each in wood	
	$180 each in aluminum	
Slip jackets		
12" x 12"	$30 each in wood	
	$40 each in aluminum	
24" x 24"	$40 each in wood	
	$70 each in aluminum	
Pneumatic rammer		$125
Plain jolt machine		$425
Jolt squeeze machine		$500
Jolt squeeze machine with pin flask lifting		$650
Stationary roll-over machine		$2750 (for flask 30" x 32")
Sand-slinger		$9,000
Mono-rail		$3.00/lineal ft. erected
Light roller conveyor		$8.00/lineal ft. erected
Fork lift truck		$3,880 - 2000 lb. capacity
Travelling cranes (30' span and 50' runway)		$15,000 - 15 ton capacity erected
		$13,000 - 10 ton capacity erected
		$10,000 - 5 ton capacity erected

QUESTION

Determine all the necessary moulding equipment that would be required in an economical foundry to make castings for the Dominion Electrical Equipment Company.

MODERN STEEL CASTINGS COMPANY

Modern Steel Castings was purchased by the Martin Manufacturing Co. Two weeks after the purchase was concluded the plant burnt to the ground. It was now necessary to design a completely new, modern, well-equipped plant with adequate room for expansion. The product was to be restricted to low carbon, steel casting production.

The plant was essentially a jobbing shop. It did have 40% of its sales that were capable of continuous production. These were rear axle housings for buses and trucks and "fifth" wheel bases for truck trailers. These castings on the average weighed 300 pounds. Of the other products the average weight was 20 pounds. The maximum weight of a single casting had been 2000 pounds. Annual sales were $3 to $4 million annually with average production 600 tons/month.

Previously the plant had operated with 200 employees on 2 shifts, 8 hours a day for 5 days a week. It had taken 80 man hours to produce one ton of castings. The total plant area had been 66,000 square feet. Their previous equipment had contained the following items:

1 electric arc furnace - melted 3 tons of scrap steel/hour
12 heats poured per day to total
9500 lbs with a yield of 55%
2 annealing ovens - 6 cars with transfer section
1 sandslinger - floor molding - for large castings
3 jolt roll over machines - for medium castings
6 jolt squeeze machines (50% of volume) - for small castings
1 small core blower
2 small core ovens - pouring done on conveyors
1 fork truck
1 shake out
8 swing grinders
1 shot blast machine
1 Wheelabrator machine
6 cut-off torches
1 100 ton hydraulic press
2 sand mullers

Few dry sand molds were made. Sand losses had been about 1 ton/ton of cast metal or approximately 900 tons/month.

QUESTION

Prepare a complete equipment list and draw a plant layout to a scale of 1/16" = 1 ft.

ST. LAWRENCE STEEL FOUNDRY

For years St. Lawrence has been a relatively small jobbing foundry with a good reputation for quality castings and service. Nevertheless, they recently experienced a very cyclical volume of business due to the increasing competition in industry. In order to keep their experienced men gainfully employed, the company wants a "bread and butter" line. This must be an object that can be mass produced in a foundry, and kept in stock at all times. The casting also must have a high steady sales volume.

A market survey indicated a need for a good strong chain for log conveyors. Those presently in use were either forged or welded. Great difficulty was encountered when these chains broke as frequently happened under overload conditions. For instance, when a vertical conveyor that hauled logs from a mill pond to the saws (a distance of 350 feet) broke, several tons of chain had to be pulled up hill before the two sections could be joined. In the past, sales of this type of chain had been at a high level and constant all year round.

The executives of St. Lawrence asked their metallurgist if a superior chain could be cast in steel. He replied "Yes, but it might be hard to set up on a production line basis due to the amount of core work required." It was decided to try a sample chain anyway.

The material was to be a manganese steel. It has high strength and great ductility after heat treating. Cold working develops a glassy smooth hard surface without lowering the ductility. This material cannot be machined. It seems to be superior to other chain metals because its surface hardness will prevent one link from working into another one; also, its strength and ductility is higher giving a better safety factor.

EXHIBIT I

Chain Data

Material	Manganese steel
Inside length of link	6"
Inside width of link	3"
Inside end radius	1 1/2"
Cross-section of link	1" square
Standard molding box	24" square

QUESTION

Can the chain be cast on a production line basis? Explain how you arrived at your answer.

STANDARD GUMMED PAPER CO.

The Standard Gummed Paper Company was engaged in the manufacture of a variety of small rolls of paper for gummed tape dispensers and tabulating machines. Many of the tapes had an adhesive coating on one side. Others were coated or impregnated with special materials to improve the physical properties of the original paper.

This process involved running the paper in mill roll width over a coating roller before the paper was slit to the required final width. The coating roll had its lower side immersed in a trough of the coating liquid. The amount of the coating applied was a function of the speed of the roller and the depth to which the roller was immersed in the liquid. To vary the immersion depth, the trough could be raised or lowered by two hand screws. These turned in the large round hole at the bottom of the bracket shown in Figure 1. A rectangular lug at each end of the trough fitted into the side of the bracket which travelled vertically on a trapezoidal bar.

The coating machines had recently been widened by extending the various rolls and troughs. However, the trough bracket had proven to be too weak to carry the increased load. One had failed already and the other 9 were likely to give way very shortly. Since production was already held up on one machine, the company engineer, Mr. Heany, had to have new brackets sand cast in steel and machined at once.

The pattern works with whom Standard Papers usually dealt could not supply the necessary pattern for a week. However, Mr. Heany knew of a foundry which would give him 10 castings off the pattern the day it was received. So Mr. Heany decided to have his own shop make the pattern. There were carpenters and machinists with all the usual wood and metal working machinery, but no one in the shop was familiar with pattern making techniques. So Mr. Heany had to make a detailed pattern drawing and explain to the boss carpenter why all the alterations were necessary in the pattern in order to get a sound casting.

QUESTION

How would the pattern differ from the bracket shown in Figure 1 and how would these changes be justified to the boss carpenter?

EXHIBIT I

Symbols Used on Pattern Drawing

C.P.	-	Core Print
Chk.	-	Check
Cpe.	-	Cope
Cl.P.	-	Class of Pattern
Dr.	-	Draft
Drg.	-	Drag
D.Shr.	-	Double Shrinkage
f	-	Finish
ff	-	Double Finish
Pl.M.	-	Parting-line of mold
Pl.P.	-	Parting-line of pattern
R. and L.	-	Right and Left
Shr.	-	Shrinkage
W. Wk.P.	-	Wood working pattern

EXHIBIT II

Approximate Minimum Tolerances for Sand Castings

Metal	Minimum overall dimensional tolerance, in.
Cast iron	1/16
Malleable iron	3/32
Cast steel	5/32
Aluminum alloys	5/64
Magnesium alloys	11/64
Brass	3/32
Bronze	1/8

STANDARD GUMMED PAPER CO.

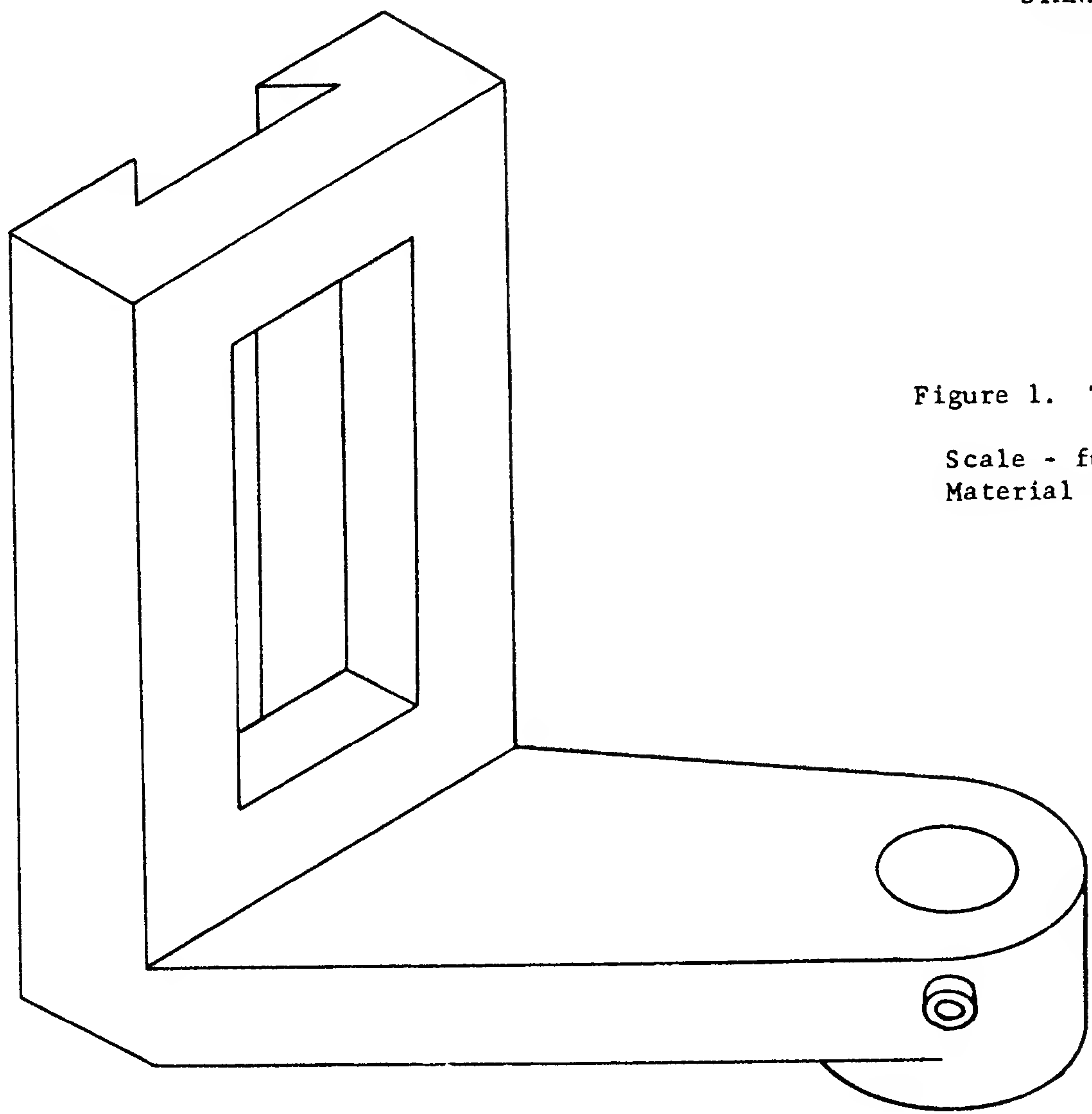


Figure 1. Trough Bracket

Scale - full size
Material - cast iron

THE NAMEN PUMP COMPANY

Namen produced a complete line of pumps in all sizes to handle any fluid. They were approached by a refinery who wanted 8 special pumps in a hurry. Namen did not have the pump required in stock. They did have patterns for a pump of the proper size and characteristics but it was not designed to meet the pressure requirements of the refinery.

EXHIBIT I

Comparison of Pumps

	Namen (N-15)	Required by Refinery
Pressure	30 psi	120 psi
Flow	15 gpm	60 gpm
Fluid to be pumped	water	high octane gasoline
Case material	C.I.	
Impeller material	Bronze	

Due to the urgent need of a refinery for these pumps, it was decided to use the standard N-15 pump. The only difference would be in the material of the case. This was to be cast in steel instead of iron. This pump is shown in Figure II.

Accordingly, the pattern for the N-15 pump was sent to a steel foundry. No special instructions were considered necessary and the patterns were rushed through moulding. Before castings were made Namen's Sales Manager advised the foundry that to ensure sound castings Namen was going to subject all the pump casings to a water pressure test of 175 psi. The foundryman complained that this was a special condition and that the pattern should be redesigned to avoid casting problems. There was not time to redesign the pump and get new patterns made, so the foundry was told to do the best it could and that Namen would buy any good castings whether or not they passed the pressure test.

The foundry made 10 castings. Only 8 were good enough to send to Namen. Of those, 5 did not pass the water test. All in all, 26 castings were made before Namen received satisfactory ones. In the rest, cracks were visible in the web reinforcing of the support, or porosity due to fine hair-like cracks around the suction inlet, the cover opening, and the boss on top caused rejection. On many cases the name was not distinct.

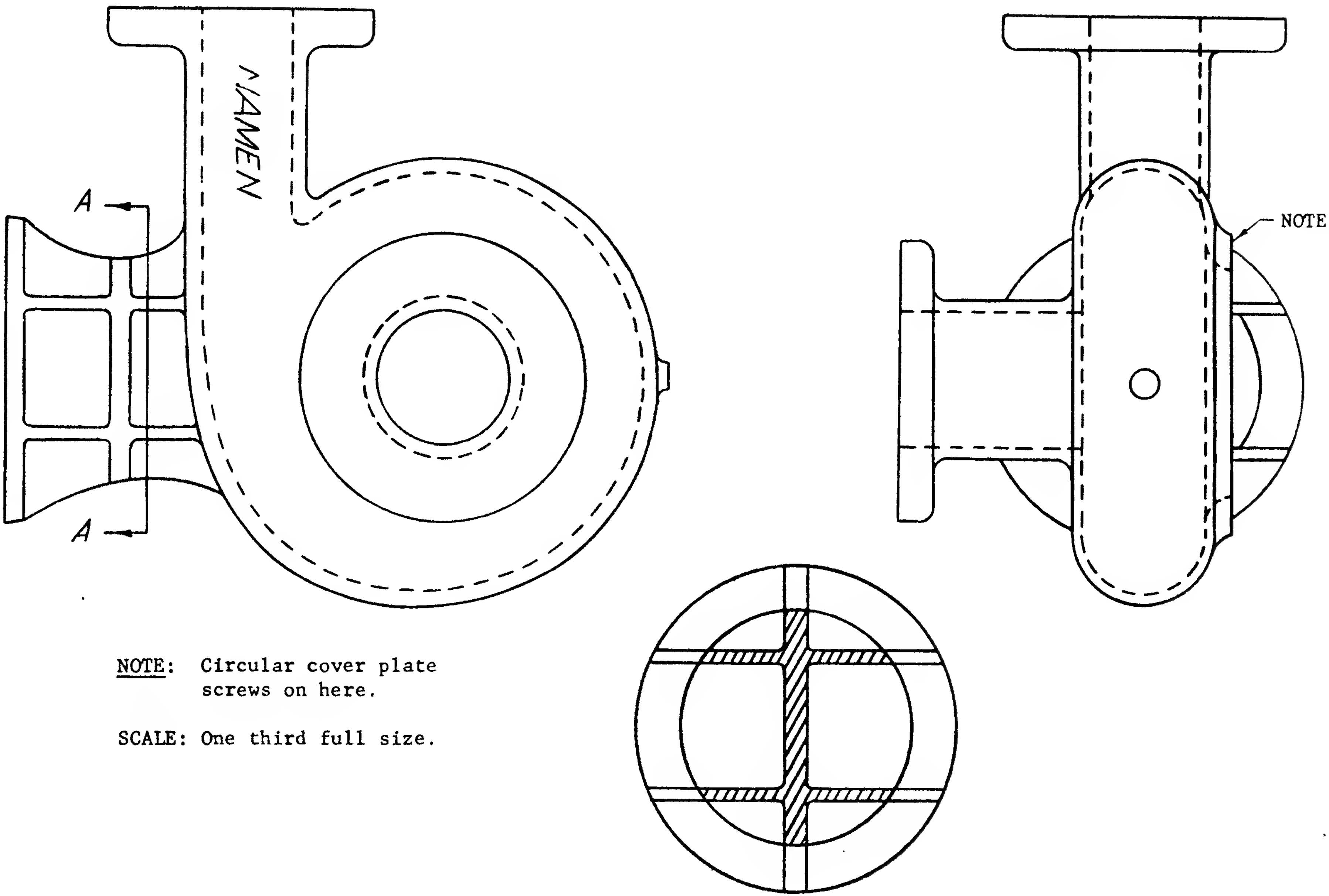
EXHIBIT II

Specific Gravity at 60° F	
Water	1.00
Mineral Oil	0.86
Ether	0.74
Gasoline	0.66 to 0.75

QUESTION

What caused the defects and how could they be avoided in a new design?

How would the pattern and cores be placed in the mould?



NOTE: Circular cover plate screws on here.

SCALE: One third full size.

Sec. A-A

B.C. VENTURES LTD.

In 1954 this company, which had been successful in the mining and refining of base metals, became interested in promoting a primary iron and steel industry for British Columbia. An investigation was made to determine the size of the potential market and the availability of raw materials. From an analysis of the information collected it was hoped a decision could be made about setting up a steel industry in British Columbia to reduce B.C. iron ores for the production of primary steel and iron products.

It was revealed that in 1881 a furnace had been set up in the state of Washington to reduce iron ore from Texada Island, B.C. But it was closed in 1919 as being an uneconomical operation. At present there is no new steel produced in B.C. from iron ore. However, one company is melting scrap iron and steel in an electric furnace to make 30,000 tons of steel a year. This is used by the company to produce 30,000 tons of light cold rolled shapes such as bars, rounds, angles, etc. There are other small companies making steel, chiefly for casting purposes. They also use electric furnaces to melt scrap making another 10,000 tons/year of steel.

The present demand for iron and steel products in B.C. is shown in Exhibit I below.

In 1939 the per capita consumption of ingot steel in B.C. was 190 lbs. This rose to 480 lbs. by 1953. Canada as a whole in the same year consumed 793 tons/person as compared to 1137 tons/person in the U.S.

EXHIBIT I

1953 Demand for Iron and Steel Products

For B.C.	50,000 tons	- bars, rods and light shapes
	60,000 tons	- med. and heavy structural shapes
	20,000 tons	- plates
	28,000 tons	- sheets
	45,000 tons	- tin plate
	12,000 tons	- pipe
	24,000 tons	- wire
	3,000 tons	- bolts, screws, etc.
	1,000 tons	- pig iron (for cast iron)
B.C. Demand	243,000 tons	
Alta. Demand	252,000 tons	
Man. Demand	160,000 tons	
Sask. Demand	80,000 tons	
Western Canada	735,000 tons	

The known deposits of iron ore in B.C. are located in or near Vancouver Island. This is close to the lower mainland where 90% of the population is located. Reserves of magnetite ore in these deposits are estimated at 5 million tons but only 2 million tons have been proven to be there. In the past this ore has been exported to Japan. In 1953, 2 million tons were exported but recent increases in ocean freight rates are expected to reduce ore shipments to Japan to 200,000 tons in 1955. This ore analyzes at 57% iron with 0.12% sulphur.

Coal is found extensively along both the Atlantic and Pacific seaboards. Currently 90% of the coke is produced in the east. Reserves of coal in B.C. are 9 billion tons or 20% of Canada's reserves. Coal found in Vancouver Island area is unsatisfactory for metallurgical use. But, 700 miles east of Vancouver the Michel field produced 240,000 tons of quality coke in 1953. This was 5.5% of the coke produced in Canada.

When producing steel in an electric furnace it is most economical to use scrap iron and pig iron in equal proportions. It is estimated that B.C. will yield 45,000 tons scrap/year. Alberta is expected to have 20,000 tons of scrap/year. But much of that would be used if a proposed steel mill is erected at Edmonton.

Limestone is found chiefly in the coastal regions of B.C., however, the province generally is rich in the material. It is inexpensive and can be shipped easily almost anywhere in the province for very little.

The Consolidated Mining and Smelting Co. at Trail, B.C. has over the years accumulated a dump of tailings from its operations. These concentrates contain about 45% iron. A conservative estimate of this dump is 13 million tons. It is increasing daily at a rate of 900 tons.

EXHIBIT II

Cost of Raw Materials

Magnetite	$9.50/ton	at Vancouver, B.C.
Limestone	6.50/ton	at Vancouver, B.C.
Coke	14.00/ton	at Michel
Coke breeze	5.00/ton	at Michel
Freight	6.00/ton	from Michel to Vancouver
Electric power	3 mills/KWH	at Vancouver
	1 3/4 mills/KWH	at Trail

EXHIBIT III

Cost of Pig Iron

Ontario	$30/ton at steel mill
Pennsylvania	$33/ton at steel mill
B.C. (in Vancouver)	$50/ton at steel mill
Australia	$65/ton at Vancouver
Canada (Eastern)	$85/ton at Vancouver

Australian pig iron is produced inexpensively. They use electric furnaces with a capacity of 100 tons/day. Power costs them 1.4 mills/KWH. Their furnace is rated at 13,200 KVA. The coke mixture is 50% coke breeze and costs $16/ton. A furnace of equivalent size would cost $2 million dollars in Canada. Building and equipment to service it would cost another 2 million dollars. A pipe mill of 10,000 tons/year capacity is proposed for Vancouver at a cost of $5 million. A blast furnace to produce 600 tons pig iron/day would cost $10 million.

QUESTION

What kind of furnaces would be used if iron ore could be economically smelted in B.C.?

HINTON STEEL MILLS

Hinton Steel was anxious to improve their billet casting facilities that produced steel for their rolling mills. They hoped to replace their present system, which produced 300 pound steel billets of 6" x 6" cross-section with one of 3 patented continuous casting processes.

One such process was the Rossi-Junghans reciprocating mold process. This system was installed at Atlas Steel Co.Ltd., Welland, Ontario in 1954. It produced 5 1/2"x 21" slabs at the rate of 40-50 tons/hour. It is the most common method in use and is widely used in Europe.

The Babcock-Wilcox process has only a single installation. It was installed at the Babcock Wilcox plant in Beaver Falls, Pa., in 1946. The capacity of this installation is 96 inches/min. of ovals and squares up to 7" and slabs 3" x 15". The process utilizes a stationary mold with intermittent billet withdrawal. Control is achieved with pinch rolls.

The British Iron and Steel Research Assoc. (B.I.S.R.A.) developed a spring mounted mold that allows the mold and billet to move together until the friction between them is less than the spring force. Then the mold snaps back to the original position. A 30 ton/hour unit was set up in Sheffield, England, in 1954. Its capacity is 4" x 4" billets.

EXHIBIT I

Estimated Operating Costs
Continuous Casting

Production: 4000 tons - 3 shift - 5 day week - 1 month.

Labour	$6,000
Maintenance, Repair	6,600
Oil, Air, Propane	2,700
Operating Supplies (brick, etc.)	4,000
Cutting Supplies	1,600
Mold Cost	1,000
	$21,900

Production Costs	$5.48/ton
Fixed Costs	1.88
Royalty	.50
	$7.86/ton

HINTON STEEL MILLS, Con't.)

A preliminary engineering report indicated that continuous casting would increase present operating costs from $5.30/ton to $7.86/ton. However, it was expected that the yield would increase 85% to 91%. Thus a total saving of $4.70 - $2.56 = $2.14/ton was estimated. Depending on the process savings of $2.14 to $4.01 per ton had been obtained.

QUESTION

Should Hinton install continuous steel casting?

Which process would you recommend?

FOREST YARNS LTD.

Forest Yarns Ltd. specialized in making knitting and fine worsted yarns. After the yarn was spun, it had to be scoured in a caustic solution before it could be dyed.

The scouring machine consisted of two conveyor chains that ran within 4" of one another. The skeins of yarn were held between the two chains and made three passes through the scouring bowl before going through a pair of squeeze rolls.

The chains were made of Link-Belt No. 462 pintle chain links (Figure III). The usual 7/16" diameter riveted pin was replaced with a 7/16" rod 30" long. A pintle link was welded on each end of this rod to make a conveyor chain 30" wide.

The present conveyor chain at Forest Yarns Ltd. was made of malleable iron with cold rolled steel rods. These had given trouble in the past due to rust spots forming on the metal. This contaminated the yarn and gave uneven dyeing. Since the two chains were of different lengths and went at the same surface speed, the shorter one had worn more than the longer one. This increased the pitch length on the small one changing slightly the surface speed of the two chains since they were sprocket driven. This tended to ball up the skeins and tangle the yarn.

The dyer finally persuaded management to repair the conveyor chains. The plant engineer prepared an estimate of $1415 to replace the chains completely. Management hesitated to spend this money and still have the possibility of rust spots. The dyer pointed out that as long as the chains were kept immersed in the 5% soda ash solution, the rust problem was not severe. But he would like all stainless steel.

Meanwhile, the chain broke. The last of the spare pintle links were installed. Yet another break appeared imminent since over 150 links were almost completely worn through. The problem of balling the skeins became acute but the engineer overcame this by putting a larger gear on the drive of one chain. The situation was further complicated by the fact that Link-Belt only had 105 malleable iron links in stock. They could get more in any material but delivery would be in 8 months.

QUESTION

1. If you were the chief engineer of Forest Yarns, what action would you recommend to management?

2. If you were going to have links cast how would you recommend that they be cleaned at the foundry?

FOREST YARNS LTD.

EXHIBIT I

Chain Data

Chain Lengths	165' 9"
	48' 0"
Chain Width	2' 6"
Links/10'0"	73
Pitch (average)	1.634"
Wt/bare link	
Material malleable iron	.342 lbs. (without pin)

EXHIBIT II

Preliminary Estimate of Replacement Chain

Links - malleable iron 3000	$600
Rods - CR 7/16" x 3' 0"	220
Labour - to install chains	325
Total	$ 1145.00

EXHIBIT III

Weights of Castings and Pattern Materials

Malleable iron	474 lbs/cu.ft.
Aluminum alloy	180
Aluminum bronze	481
Steel	480
Yellow Pine	34
Stainless Steel	495

EXHIBIT IV

Cost of Patterns and Castings

Split pattern of one link (yellow pine)		25.
Match plate - 12 links (aluminum alloy)		180.
Steel (cold rolled rod)		10 cents/lb.
Stainless Steel		95 cents/lb.
Aluminum bronze		54 cents/lb.
No. 462 pintle link from Link-Belt Co.		
Malleable iron		20 cents/each
Stainless steel		42 cents/each
Aluminum bronze		42 cents/each
Casting of links	for 50	for 3000
Malleable iron	50 cents each	15 cents each
Steel	85 cents each	28 cents each
Stainless steel	90 cents each	45 cents each
Aluminum bronze	85 cents each	34 cents each

FOREST YARNS LIMITED

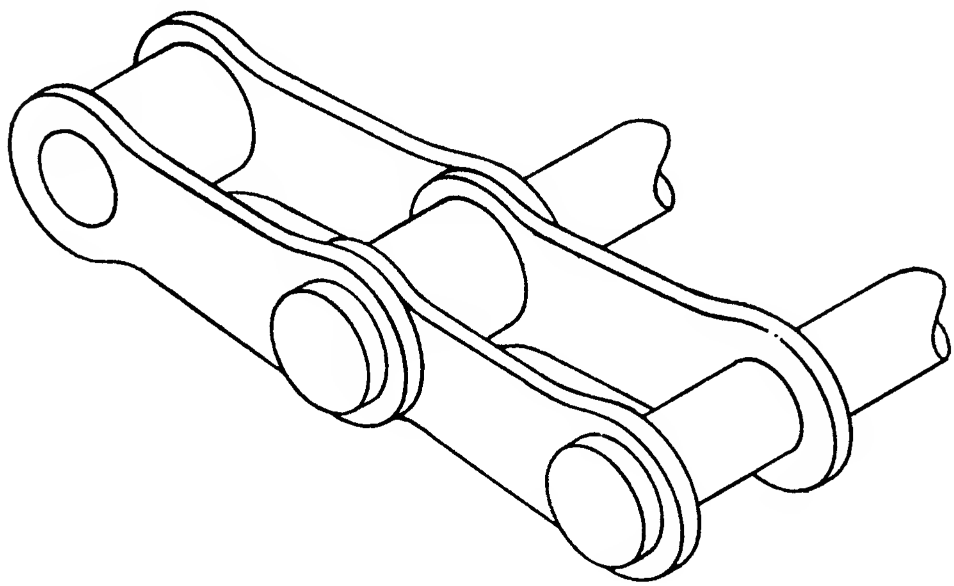


Figure III
Conveyor Chain
(No. 462 pintle links and 7/16" rods with riveted ends.)

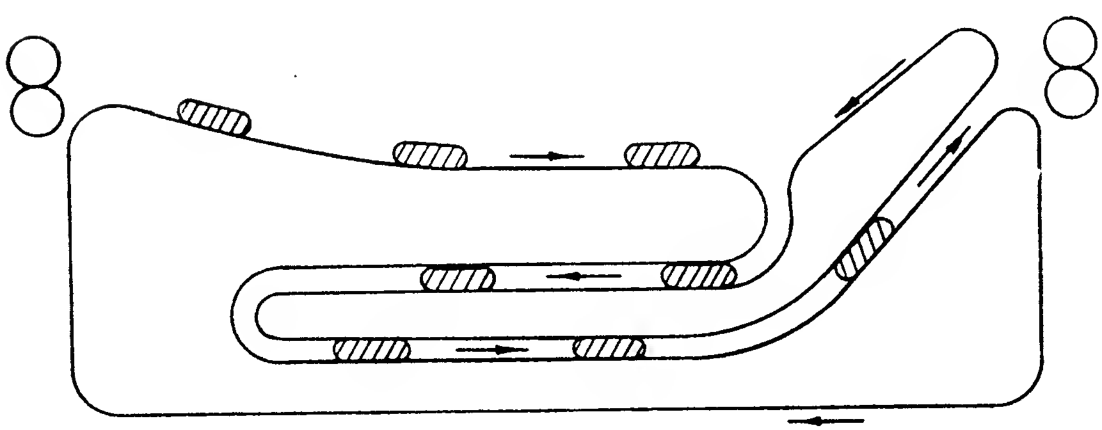


Figure IV
Elevation through scouring bowl

Path of chain

Skein of yarn

Squeeze rolls

KLEEN WASHING MACHINE COMPANY

The Kleen Washer is one of the best selling washing machines on the market. The company makes a complete range of models which it distributes nationally. On a certain wringer type washing machine monthly sales were estimated for 1955 at 1000 units.

This particular washing machine had just been redesigned and some new parts were required. One such part was the wringer drive shaft bearing bracket shown in Figure V. The bracket fastens to the wringer frame with four machine screws. The drive shaft has a shoulder below the bracket and passes through the round hole. A tube presses over the extended ring to enclose the rotating shaft.

The trial run of 1000 units of the new design was to be made. It was necessary to decide how the bearing bracket should be manufactured. Sand casting in aluminum or die casting in zinc alloy were the alternatives being considered.

For sand casting, a match plate with four brackets mounted on it could be used. The round hole only was to be cored and the rest of the bracket would be solid. The aluminum match plate and metal core box would cost $250. It was estimated that one mold, complete with cores, could be made in 3 minutes.

Die casting would be done on a machine with a two directional die pull. Thus the inside of the bracket and the bolt holes could be cored. The metal saving as a result would be 17%. Dies for the operation would cost $550. Production would be at the rate of two castings per minute.

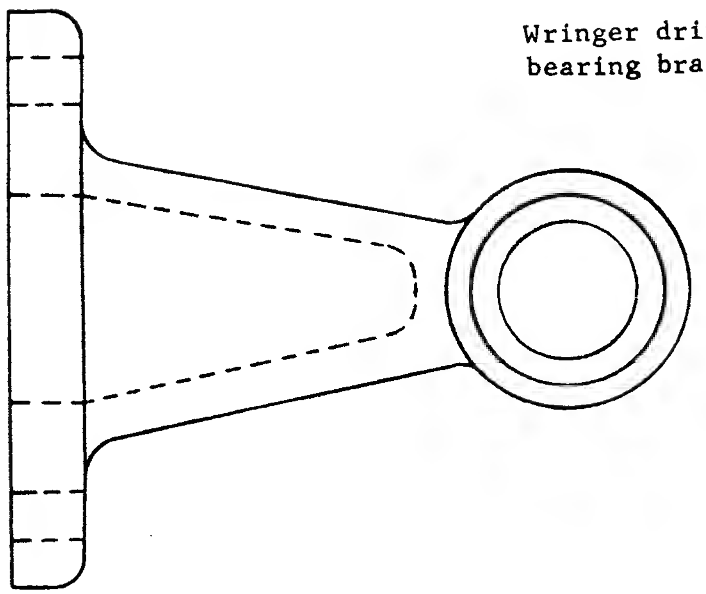
For the two materials the weight and strength figures are shown below. Material costs are about the same, $.30/lb. However, the zinc die casting scrap could be reused, whereas the aluminum alloy could not. This meant that the loss of aluminum alloy was 10% as compared to 5% for the zinc alloy. The labour rate for either method was $1.80/hr. The weight of the die cast bracket would be 1.4 lbs.

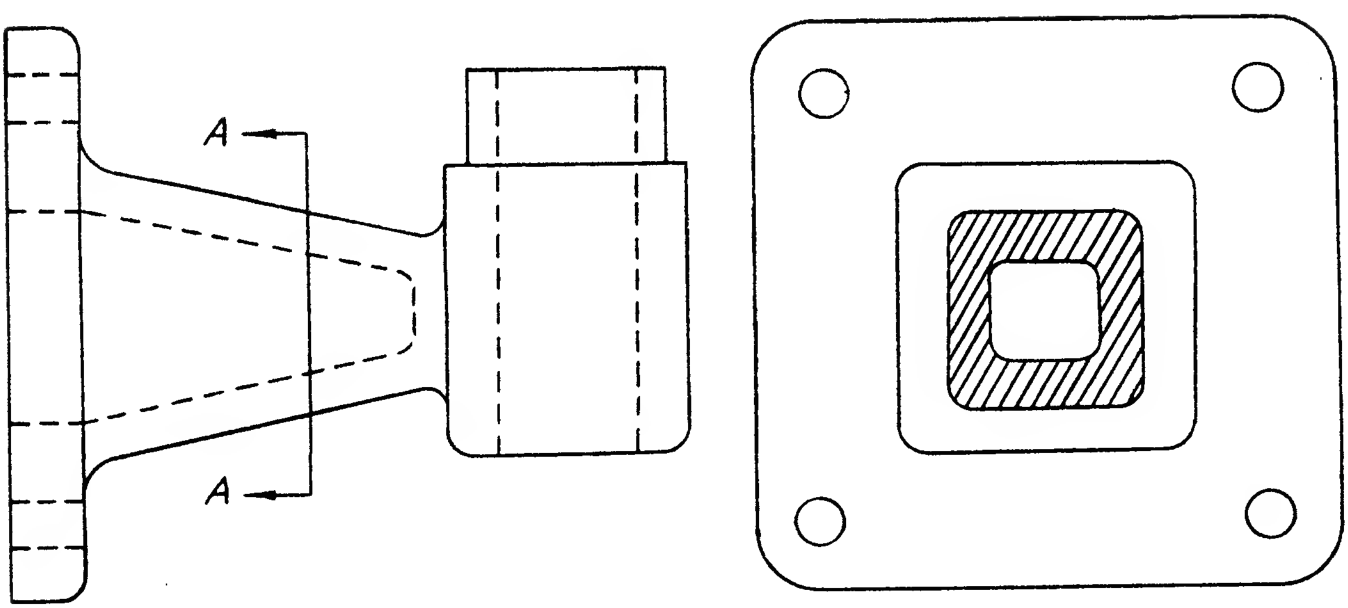
<u>QUESTION</u>: Which would be the most economical method of manufacture?

Material	Sand Cast Aluminum	Die Casting Alloy
Ultimate tensile strength (psi)	22,000	48,000
Specific weight (lb/ft^3)	169	418

KLEEN WASHING MACHINE CO.

Wringer drive shaft
bearing bracket





Sec. A-A

DIE CASTING
SCALE - FULL SIZE

KLEEN WASHING MACHINE (Con't.)

EXHIBIT I

Standard Times for Operations

Drill 4 holes 1/4" diam. x 3/8"	- 1/4 min.
Drill 1 hole 3/4" diam. x 2"	- 1/6 min.
Ream 1 hole, 3/4" diam. x 2"	- 1/6 min.
Reduce diam. 1/8" x 3/4" long	- 1/2 min.
Face base 4" square	1 1/2 min.
Clean 1 small casting (sand)*	- 1/4 min.
Trim flash on a casting	- 1/12 min.
Tumble castings	- 45 min.
Set-up per machine operation	- 30 min.
Sand casting (pouring, shake-out, and core making)	- 3 min.

*(cut off sprue, etc., and grind)

DRYDEN ENGINES LTD.

This company was a large producer of internal combustion engines for the automotive industry. Castings were purchased from foundries but all machining and assembly on the component parts was done in the Dryden shops.

Prior to the second world war, cast iron pistons had been used in the engines. But during the war aluminum pistons were used on aircraft engines with success. So after the end of the war Dryden Engines Ltd. considered changing to aluminum pistons. At first these were sand cast. However, it soon became apparent that other casting methods had advantages that should be considered. Consequently, a study was made of the requirements of the aluminum piston to determine the best method of casting.

The piston had to be free of porosity in the cast metal. The surface needed to be smooth and have a sharp outline. This would provide savings in machining. If possible, a hard or dense exterior would be desirable on the casting. The metal should be as strong as possible after the casting process, even though some cross-sections were thin.

Besides having these desirable physical properties, the casting had to be economically produced. The cost of pattern or mold per piston had to be low, yet the parts had to be produced at a high speed. The labour cost per casting had to be kept at a minimum including the labour for making patterns, match plates, and metal molds or dies. Production would be done in large quantities so possible savings in machining would be an important factor in selecting the type of casting method.

The production engineer of Dryden knew that sand castings usually involved low pattern costs but had high labour costs. He also knew that plaster of paris molds made excellent castings with close dimensional tolerance. He did not know if aluminum pistons could be satisfactorily die cast nor did he know if permanent molding would give a sufficiently good piston casting to warrant the extra expense for molds. He therefore set out to compare all these processes and investigate others such as centrifugal and "lost-wax" methods to determine the most economical one for producing aluminum piston castings for the company.

QUESTION

Compare the following casting methods and determine the most satisfactory one for making the aluminum castings:

Sand	Lost-Wax
Permanent mold	Centrifugal
Plaster of Paris	Die Casting

VOLCANO OIL BURNERS LTD.

Originally organized in 1886 as a foundry, Volcano has continued to grow and expand. For many years this manufacturer of oil burners has been recognized in the industry as one of the leaders in manufacturing horizontal rotary burners for industrial, commercial, and residential use.

The company maintains a well staffed home office engineering department. They have five manufacturing plants, three in the western United States and two in the New England States. Parts and service are an important part of the business so each burner improvement is designed to be largely interchangeable with older Volcano burners.

In line with a sales promotion program it was decided to have scale models made of a standard fully automatic, industrial Volcano oil burner. These were to be provided free of cost to Volcano suppliers and were to be distributed among their better industrial customers. It was hoped that the model could be set on a suitable base so that it could be used as either a paper weight or an ash tray.

To meet the design requirements the model would have to be made to a scale of 1 inch to a foot. Thus the overall model size would be about 2" wide x 3" long and 2" high. Excellent reproduction of fine detail would be essential. It was hoped that even heads of assembly bolts, piping, and electrical conduit could be shown. Particularly the name, "Volcano," would have to be clearly reproduced. To keep costs low no machining could be done on the model, yet surface finish would have to be smooth.

One of the head office engineers was given the problem and asked to determine if the model could be made economically. Preferably, the model was to be cast in one of the company's foundries. However, at first glance it appeared that the assembly could not be cast.

To show the following details seemed to require such extensive core work and intricate parting lines that casting would not be feasible:

- rotary unit casing
- atomizing nozzle
- hinged burner mounting
- main motor and drive
- scanning photo electric units
- oil meter and reservoir
- oil preheater
- damper motor and control
- piping, fittings, and valves
- electrical connections

Volcano already owned and operated cupolas and crucible furnaces for melting ferrous and non-ferrous alloys. They commonly used sand molds and permanent molds and on occasion had done centrifugal casting. They did not own a die casting machine.

QUESTION

In a report, compare the following casting methods and determine the most satisfactory one for making 5000 models in metal.

Sand	Lost-Wax
Permanent Mold	Centrifugal
Plaster of Paris	Die Casting

PIPING SPECIALTIES COMPANY

This company made a variety of special pipes, fittings and valves. These were made principally for the brewing, dairying and oil refining industries.

The nature of the work in these fields frequently involved the use of heating and cooling processes. This was accomplished by passing a fluid or gas over banks of pipe coils that contained a fluid or gas at a different temperature. The whole unit was encased in a closed or open shell.

Usually when a company had a heating or cooling process it was most economical to make the required unit in the company machine shop. This was possible because such units with their tremendous number of pipes had an extremely high labour cost. Thus a small company could buy standard pipe and fittings and use their own pipe fitters. If extra help was required, unskilled men would be used at helpers rates. In this way, a company could save as much as 30% on the cost of a $3000 coil unit, even if they had to purchase a specially made shell.

Executives of Pipings Specialties were aware of this situation. Because the company did not sell standard piping, it was hoped that a new product could be developed to extend the company's market into the heating and cooling coil field.

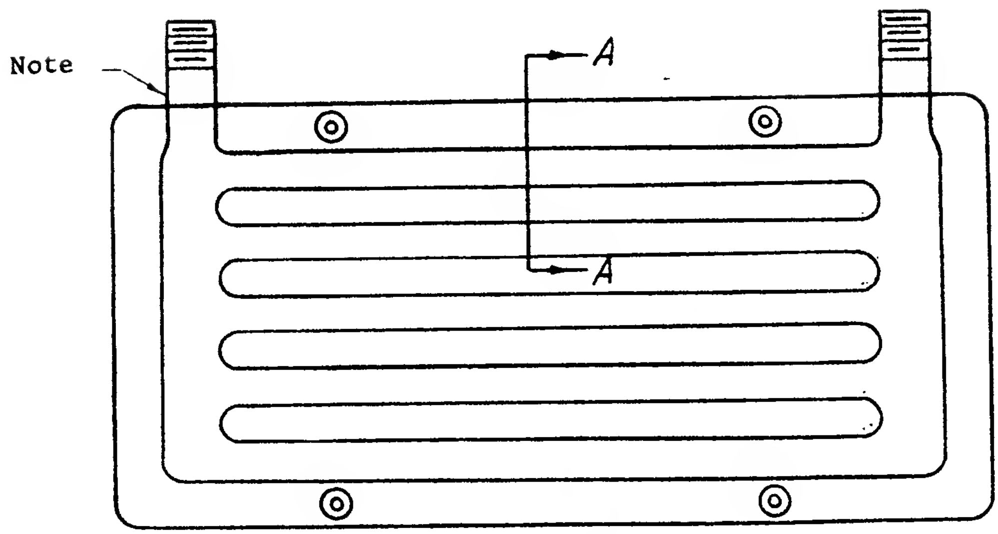
Finally, the design shown in Figure VI was selected. It consisted of two identical steel stampings fastened together to form a parallel path for a fluid passing through the coil. A standard pipe fitting was made for the inlet and outlet of the coil. Four studs were placed on one face of the coil so that several plates could be fastened together with a fixed space between them. It was hoped that these plate coils could be mass produced to replace coils of standard pipe.

Piping Specialties had several presses available to make the required stampings. They also had a variety of resistance, arc, and gas welding units that could be installed as part of a production line.

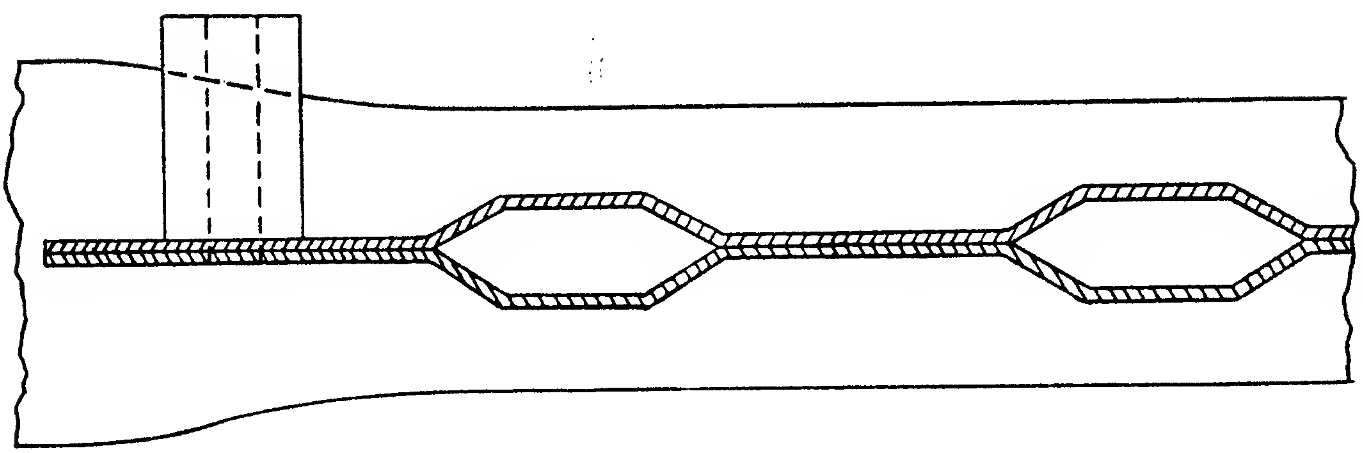
QUESTION

1. Could the company use a welding process to fabricate the coils?

2. What process would be used and what would be the various operations?



Scale 1-1/2 in. = 1 ft.



Scale - full size
Section A-A

NOTE: Either standard 2" pipe nipple or welding fitting to be fastened here.

Figure VI
Coil fabricated from light gauge sheet steel

REDMAN CONSTRUCTION COMPANY

Redman was a large contracting company. One of the jobs they were working on was the construction of a concrete gravity type dam. This was to be 3200 feet long with a maximum height of 198 feet. They were building the power house also for the development.

The site was on the Ottawa River, 300 miles above Montreal and 55 miles from the nearest town of any size. Nearby there were good supplies of sand and gravel so the company set up its own concrete mixing plant at one end of the dam close to the gravel pits. Sand was screened and sorted for size. Boulders were rejected and sent to jaw crushers to be broken. The crushed rock was then returned to the screening conveyors and continued on to the mixing plant if further crushing was not needed.

One day, the motor for one of the jaw crushers burnt out. The conveyor continued to run and boulders rolled into the crusher shed and piled up around the machine. When the rocks were cleared away, it was found that one rock had struck the side of a large drive gear. All the spokes were either broken out entirely or cracked.

The hub of the gear was not damaged nor was the rim or the gear teeth. On checking, the rim was found to be still true.

Redman had a spare motor for the jaw crusher, but no spare gears. The machine was urgently needed but a replacement gear could not be purchased from stock. In fact, it would have to be brought in from the States since a pattern was not available in Canada. This would cost $434 and delivery would take 3 weeks. If a pattern and casting were made in Montreal, delivery would be the same, but the cost would be about 40% higher.

The resident engineer knew that there were steel plates and arc and gas welding equipment available at the site.

QUESTION

Could a welded assembly be made for the gear and how much would it cost?

EXHIBIT I

Gear Data

Number of teeth	120	Pitch diameter	47 3/4"
Number of spokes	6	Hub diameter	6 1/2"
Spokes 3/4" thick x 3"		Hub length	5 1/2"
Rim thickness (Max)	2 1/2"	Bore	4 7/16"
Total weight	407 lbs.	Face width	3 1/2"

Material - cast steel

REDMAN CONSTRUCTION, Con't..

EXHIBIT II

Cost of Welds

Arc Welding

Plate thickness	3/8"
Electrode size	1/4"
Current	250 amps
Arc volts (Min.)	30 volts
Welding speed	40 ft/hr
Electrode deposition	1/4 lb/ft
Labour	$1.80 per hour
Power	2 1/2 cents/kwh
Electrode	9 cents/lb
Efficiency of welding machine	50%

Oxyacetylene Welding

Oxygen consumption	4.2 cu.ft/ft of weld
Acetylene consumption	4 cu.ft/ft of weld
Electrode deposition	1/4 lb./ft
Welding speed	7 ft/hr
Oxygen	$0.93/100 cu.ft.
Acetylene	$2.63/100 cu.ft.
Steel plate	10 cents/lb

Flame Cutting

Oxygen consumption	1.3 ft^3/in^3 metal
Cutting speed	24 ft/min.

FIELD BUSINESS MACHINES

Field Business Machines made many different types of business machines. These ran in size from small adding machines up to immense electronic computers. The company did all its own design work, manufactured all the component parts, and assembled them.

The Hamilton factory made many small parts for other plants of the company but it specialized in the production of a mechanical card sorter. This machine was some 8 feet long, 4 1/2 feet high and weighed about 350 lbs. Its design had changed little over the years and many parts were cast iron despite a recent trend to lighten the F.B.M. machines by using steel stampings.

The above plant was well equipped with machine tools. They had lathes of many sizes, shapers, milling machines, grinders, drills, and boring mills. They also had a 7 1/2 ton press and arc and gas welding equipment. One of the milling machines was set up with a pantograph attachment for die cutting. A recent production cut decreased the load on all machines. Consequently, many operators had been released and the plant went onto a one shift day.

Very little welding was presently required. The plant manager as a result wanted to let the welder go. He agreed that one of the foremen could do any welding now that there was no longer any production welding. But the chief engineer did not want to lose a good welder. He therefore decided to see if any production welding could be found to keep the man busy.

A drive assembly on the sorter caught the engineer's attention. It consisted of a cast iron cam with a hub extension of 2 1/2". A cast iron sprocket was pressed on the hub extension and the whole unit had a 1 1/2" diameter hole bored through it. The two castings weighed a total of 3 pounds of which one pound was removed by machining.

The sprocket was 1/2" pitch, 30 teeth, and 3/8" wide. It drove a light brass wire ladder chain and had overall tolerances of ± 50/1000 of an inch. The teeth were machined on a miller. Twenty sprockets were put on a mandrel and cut at once. This operation alone took 38 hours.

The cam had a 3" base circle and two lobes at 180°. This provided a lift of 3/4" ± 0.045". Both faces of the cam were machined. The 1/2" width of the edge was chilled to provide a hard wearing surface. The hub extension was turned to a diameter of 2 1/4" so that it could be held in a split babbit bearing. This bearing was the full length of the hub extension.

The engineer thought he could redesign the assembly and save money too. He proposed changing the material to low carbon steel. The hub of the cam could be made of steel tubing which would necessitate reducing the bearing size. This could be done quite simply. However, the cams and sprockets which he proposed to make out of steel plate could not be pressed on the tubing without changing the inside diameter. If he could

overcome this difficulty he felt that considerable savings could be made due to a reduction in material as well as less labour costs due to machining*. The total saving could be large since many thousands of these units were required.

*Direct costs of machining labour for the castings was 55 cents/unit.

QUESTION

How would altering the design in this way provide work for the welder?

EXHIBIT I

Comparison of Cast Iron and Steel

Ultimate tensile strength	Cast Iron	30,000 psi
	Steel (Low G)	60,000 psi
Specific Weight	Cast Iron	480 lbs/cu.ft.
	Steel	490 lbs/cu.ft.
Cost of Raw Materials	Iron Castings (2)	85 cents
	Cast Iron Scrap	3/4 cent/lb
	Steel	10 cents/lb
	Steel Scrap	2 cents/lb

EXHIBIT II

Flame Cutting Data

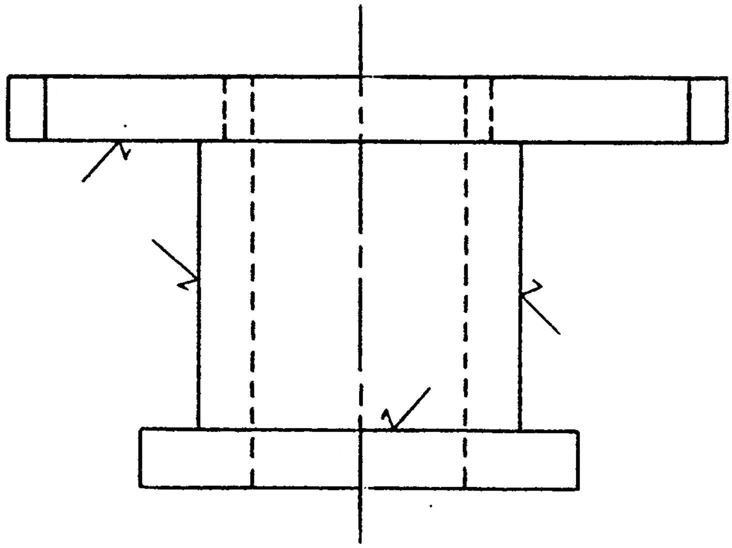
Plate thickness	1/4"
Stack height	6"
Length of cut	15"
Cutting speed (6" stack at 45"/hr)	
Tolerance	± 1/32"
Oxygen consumption	34 cu.ft./hr (at $0.93/100 cu.ft.)
Acetylene consumption	20 cu.ft./hr (at $2.63/100 cu.ft.)

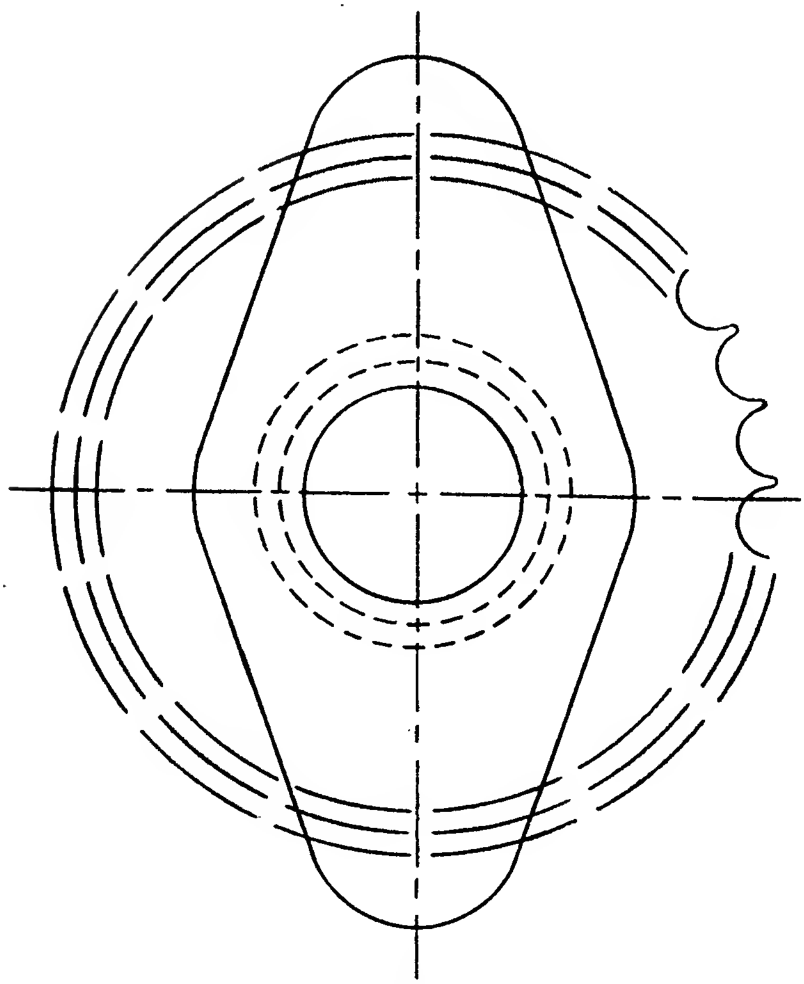
EXHIBIT III

Brazing Data

Strength of brazed joints for steel plates		Shear strength 25,000 psi
		Tensile strength 30,000 psi
Cost of brazing material		3 cents/ft
	Labour	8 cents/part
	Heat	2 cents/part
Cost of flame hardening		28 cents/ft

Scale - 3/4 full size





J.H. ANGLIN COMPANY

This company was one of the foremost companies in the heavy steel fabrication industry. They specialized in making heavy duty boilers and tanks. They had a machine shop well stocked with machine tools for handling big work. In addition, they had complete facilities for welding, riveting and forging. Much of their work was done for an adjacent marine yard and drydock which was a wholly owned subsidiary. However, a good deal of J.H. Anglin's volume of forging business came from local companies who were not equipped to handle heavy work.

The forge had three steam hammers. They had capacities of 1000, 12,000, and 18,000 pounds and could be overloaded about 75%. There were two oil fired furnaces, the largest of which could hold several 24" square billets twenty feet long. An oven for annealing was almost as large but it would take work thirty feet long. The company also had two board hammers, a 1500 ton forging press, and a 3" upset machine.

In the past, Anglin's forge had made numerous crankshafts. At present Dryden Engines Ltd. were enquiring about the cost of a forged crankshaft for a large diesel engine they were building. This crankshaft had seven main journals 8" in diameter and 4" long. It had six throws of 10" and these journals were 4" in diameter. The overall length was 8 feet and the total weight would be 3,430 pounds. Anglin's estimated it would take three days to forge the crankshaft and that it would cost $850. Material would be $520 extra of which 21% would be scrap. These figures did not include any finish machining as Dryden would do this themselves.

This crankshaft would most conveniently be made out of a billet 10" x 22". However, the nearest stock sizes rolled at the steel mill were square billets of either 12, 14, or 16 inches to a side. A special billet of the size desired would cost about 25% more.

When the Dryden sales manager, Mr. Read, received the Anglin quotation he was astounded. He knew he could get an identical crankshaft cast in the same steel alloy, SAE 1041, for $750. Consequently, he felt that the J.H. Anglin Co. was grossly overcharging him. When they told him they could not reduce the price of the forging, Mr. Read decided to have the crankshaft cast.

Dryden's chief engineer objected to this strenuously. He pointed out to Mr. Read that a forging was 100% stronger than a sand casting. Therefore, the cast shaft would have to be made 100% heavier all over. Mr. Read then said, "All right, we can cut it out of 9" and 5" round and 6" x 2" thick bars and weld it ourselves."

An estimator figured out the cost of a welded crankshaft. This came to $435 for labour only. Finish machining would cost almost the same as for the forged crankshaft. Still the chief engineer was not satisfied. He felt that such construction would be 50% weaker than the forging and that even if the crankshaft was made heavier the welds could not be relied upon for this application.

QUESTION

How would the crankshaft be made if it was forged?

How should Mr. Read have this crankshaft made?

EXHIBIT I

Tolerances of Hammer Forgings

O.D.	Tolerance
up to 12"	± 3/8"
12" to 24"	± 1/2"
24" to 40"	± 3/4"
over 40"	± 1"

BAYVIEW TECHNICAL SCHOOL

Bayview Technical School was not yet built. It was in the final planning stages with building scheduled to start in ten months. An enrollment of 1800 students was expected.

Mr. Harris of the School Board had been commissioned to recommend the necessary equipment for the machine shop. Fifty students at a time was to be the capacity of the shop. They would spend half a day at a time in the shop. Such a shop was expected to contain lathes, shapers, milling machines, drills and grinders.

At present Mr. Harris was concerned with selecting the best lathes for the shop at the most reasonable price. It was common knowledge that about one machine was needed per student. But only about 60% of the various machines needed to be lathes.

Quotations had been received from many machine tool companies. The specifications for these now had to be compared so that a final selection of types and numbers of the various models of lathes could be made. Manufacturers' literature described the various lathes as shown in Exhibit 1.

EXHIBIT I

Description of Various Lathes

1) Logan No. 1821.

A floor model lathe with a 10" swing weighing 575 pounds. The bed is ground two ways and the headstock ball bearings to carry the spindle. Twelve spindle speeds are available. Six are obtained through the direct drive and the remainder by interchanging the back gears. A half nut from the lead screw provides the thread cutting drive.

Price $940.00

2) LeBlond Regal

This is a 12" swing floor model lathe with quick change gears and 8 spindle speeds. It has anti-friction bearings in the headstock and one piece apron. The apron has pressure lubrication and felt way wipers. There is both a lead screw and a feed rod. The lathe has a chip pas and weighs 1165 pounds.

Price $2440.00

3) LeBlond Regal

The same lathe as above can be provided as a 970 pound bench model.

Price $2370.00

4) South Bend CL-670-R

A 10" swing, quick change, bench model lathe. It has 12 spindle speeds with six obtained through back gearing. Feed gears in the apron run in an oil reservoir. A spline in the lead screw provides the thread cutting drive. A safety device prevents engaging two opposing feeds at the same time. The lathe weighs 520 pounds.

Price $950.00

5) Sheldon TE-1236-B

This is a cabinet mounted engine lathe. The headstock has tapered roller bearings and the bed is precision ground. Eight spindle speeds are available, four of them by hand shifting the V-belt drive inside the cabinet leg and the rest through the back gears. The apron is double walled. There is a quick change gear box for thread cutting with the drive taken off the lead screw. The weight is 1260 pounds.

Price $2210.00

6) McDougall VDF, 18-RO

A geared head engine lathe with a 15" swing. The bed is massive with heavy ribs and hardened and ground ways. All gears are hardened and ground. There are anti-friction bearings throughout. The headstock contains a brake. Twelve spindle speeds are available through quick change gears. Power feeds are interlocked to prevent engaging more than one at a time. They are also equipped with overload protection. Over 200 thread feeds are available. There are two separate feed screws and a lead screw. Lathe weight 3,880 pounds.

Price $5,650.00

7) Dean, Smith and Grace 13 S.B.

This is a geared head engine lathe with a 13" swing. Twelve spindle speeds can be obtained through the quick change gears. The cabinet base is cast in one piece with the bed. Spindle bearings are anti-friction and the gears are all hardened and ground. Both the turret and carriage have felt wipers. There is no screw cutting, instead the lathe has a hex turret on the bed. Weight 4,000 pounds.

Price $3,450.00

8) The same lathe without the hex turret and with provision for thread cutting would cost another $160.00.

9) Optional Equipment as extras for all lathes.

1.	hex bed turret	$580	5.	taper turning attachment	$160
2.	turret tool post	70	6.	thread chasing dial	60
3.	4-jaw chuck 11"	100			
4.	3-jaw chuck 10"	150			

QUESTION: How many lathes of which types should Mr. Harris recommend for the shop?

CAMDEN MANUFACTURING COMPANY (A)

Camden was a company that got its start in the metal machining industry during World War II. Since the war they had changed from the munitions and light armaments field to general production machining. They did a large volume of business with automotive and farm implements companies who maintained plants primarily for assembly purposes.

Besides a complete line of machine tools, Camden had a great variety of lathes. They had two speed lathes, thirty-one engine lathes, three of which had gap beds. There were also three tool room lathes, seven horizontal turret lathes, two horizontal automatic lathes, and an automatic screw machine in the plant.

The turret lathes represented both the bar and chucking types. All the turret lathes had ram and saddle turrets. The ram turrets were all of the hexagon type and the saddle turrets were all square, but two of the latter also had a tool holder mounted on the opposite side of the work piece. The company also had a complete assortment of tools for mounting in turret equipment.

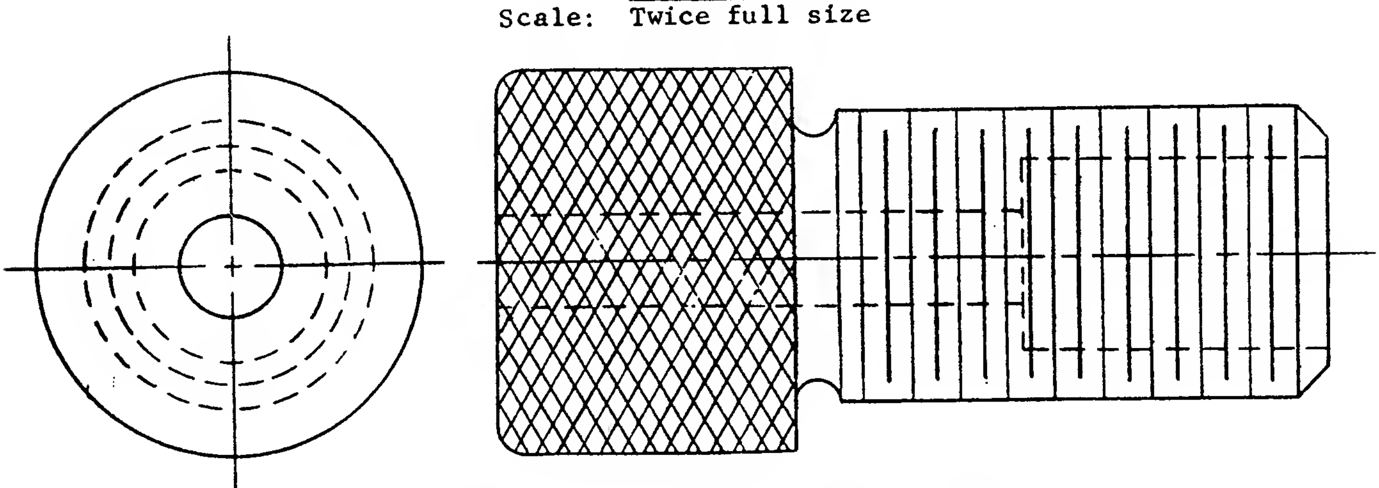
At the present time, Mr. Roberts, in the production planning department, was considering an order from Field Business Machines. It was for a trial order of 6 of the brass studs shown in Figure X. If these proved satisfactory, ten lots of 120 each would be ordered over a period of six months.

QUESTIONS

1. Would the various necessary operations (particularly threading) be done best on separate machines rather than on just one?

2. Which machines should Mr. Roberts allocate for the trial run and the subsequent orders?

FIGURE X
Brass Stud
Scale: Twice full size



Tolerance on small hole = 0.187" +.002 -.000

ST. CLAIR MACHINERY COMPANY

For many years St. Clair had made heavy machinery for construction and road building. They also made, under license, all the necessary engines for their equipment. Since they were one of the largest producers in the field, their machine shop was completely equipped with all kinds of machine tools for both light and heavy work.

Recently the company had entered into the field of fork lift trucks. The product St. Clair made had been quite successful. But now it was found that many would-be purchasers wanted the lift trucks to do jobs for which the forks were not satisfactory. Consequently a whole new line of lift attachments had been developed. These all had to fit on a standard lift plate.

The design was now approved and Mr. Bolton of the production planning department was faced with the problem of scheduling the first production run. His immediate concern was 200 shaft and lift plate assemblies shown in Figure XI. The shaft was to be made of cold rolled steel. It would fit inside a forged steel base and be welded in place. This unit would then fit on the cast steel lift plate and be bolted in place when required.

At the moment, the machine shop was not running to capacity. As a result, Mr. Bolton would have no difficulty getting any one type of machine to do an operation on the shaft lift assembly. The company had machines in their shop of the types listed in Exhibit 1.

QUESTION

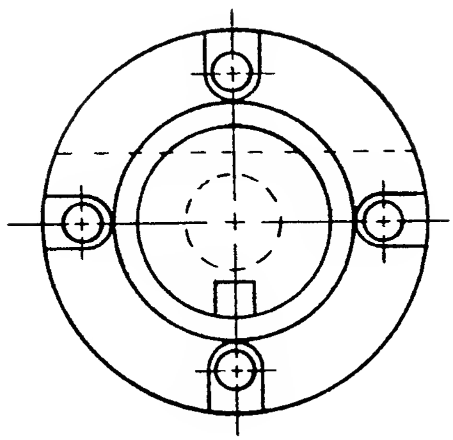
What are the various machining operations and on which machine should each be done?

EXHIBIT I

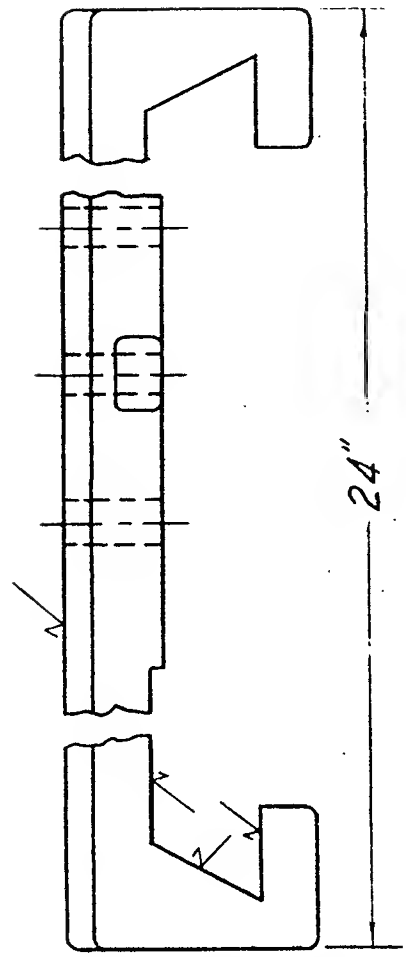
Types of Machine Tools in the St. Clair Shop

- Horizontal Shaper
- Vertical Shaper
- Hydraulic Shaper
- Pit-type Planer
- Open-sided Planer
- Plain Milling Machine
- Vertical Milling Machine
- Rotary Table Milling Machine
- Upright Drill
- Radial Drill
- Engine Lathe
- Turret Lathe

ST. CLAIR MACHINERY (Con't)



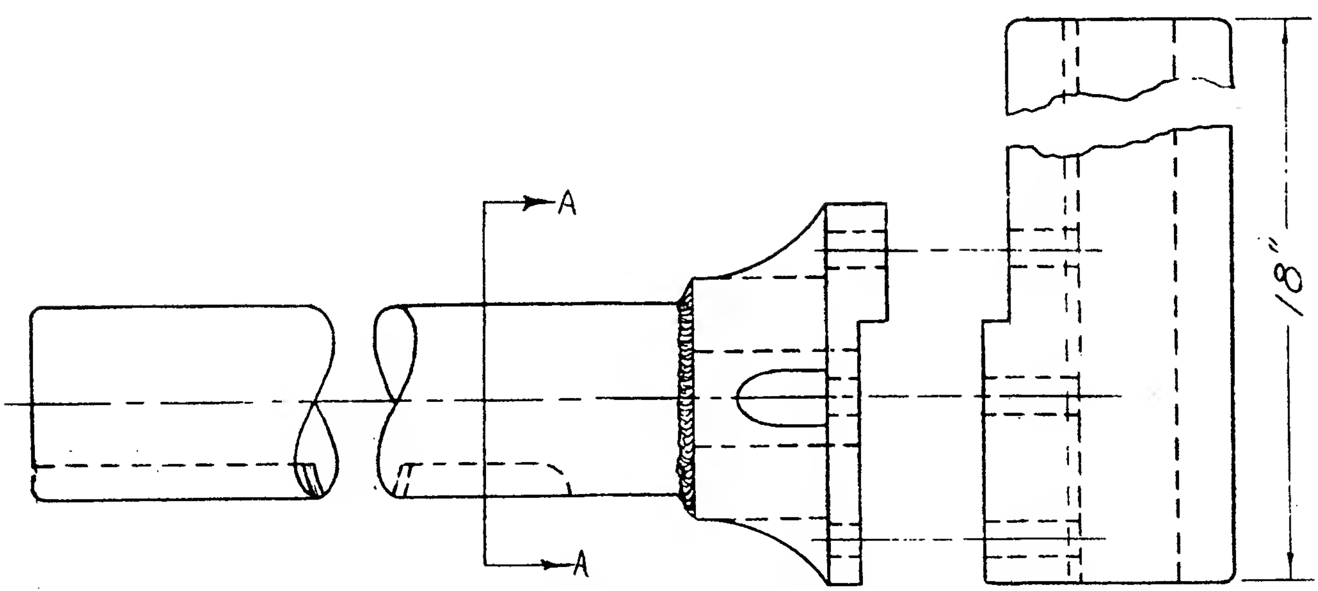
Shaft Section A - A



Plan of Lift Plate

Figure XI
Shaft and Lift Plate
Assembly

Scale: 3" = 1'0"



Elevation of Assembly

CAMDEN MANUFACTURING COMPANY (B)

Mr. Roberts of Camden had been approached by a local farm implements company to machine a cast iron gear box for them. (Shown in Figure XII.) The castings would be supplied to Camden and only the machining operations were to be done.

Since there were 2500 of these gear boxes, Mr. Roberts wanted to use jigs and fixtures and set up a proper production line. It was felt that this could be done quite simply because all the operations but one would be either drilling or boring. Tolerances would not be to close limits since the gear box was for a slight secondary drive on a combine.

The planning was completed and the first castings were machined. The work was done on the drills listed in Exhibit I. When Mr. Roberts got his first production report for the gear boxes, he was amazed to see a high percentage of rejects. He could not imagine why and went to check with the foreman.

A first year engineering student, who was working in the shop for the summer only, had been assigned to the job. He was a conscientious lad and quite intelligent, so the foreman had felt he could handle all the drilling and boring operations on the gear box. Using jigs and fixtures on all operations, the job had appeared foolproof. The only fussy operation was hole "A". Nevertheless, rejections had been made because holes were incorrectly located, not parallel to the machined surface, and oval instead of round.

To further complicate the problem, Mr. Roberts found a change notice for the gear box. This was to substitute the hole shown in set in Figure XII to replace hole B.

QUESTION

On what machines would the various operations be done and how would the rejects be eliminated?

EXHIBIT I

Drills in gear box production line

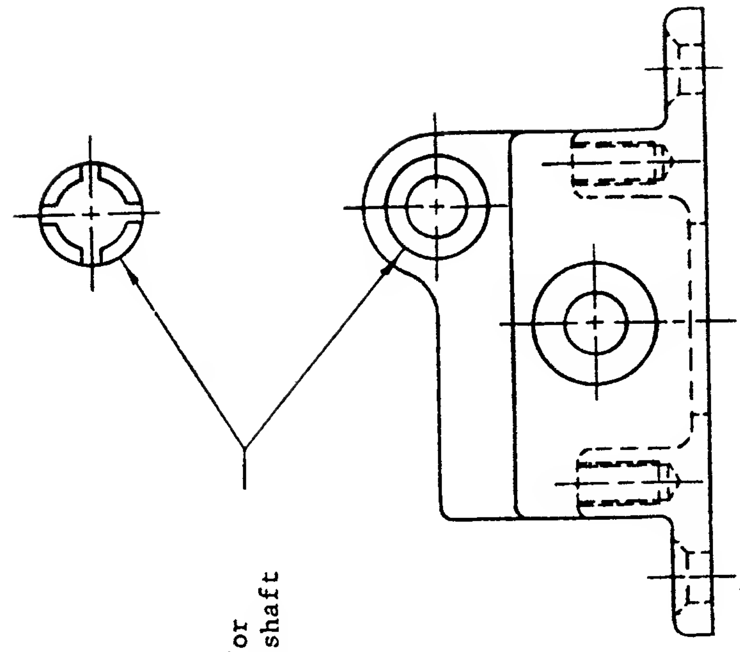
1. Radial drill
2. Boring mill
3. Vertical drill
4. Gang drills
5. Multi-spindle drills

CAMDEN MANUFACTURING (Con't)
(B)

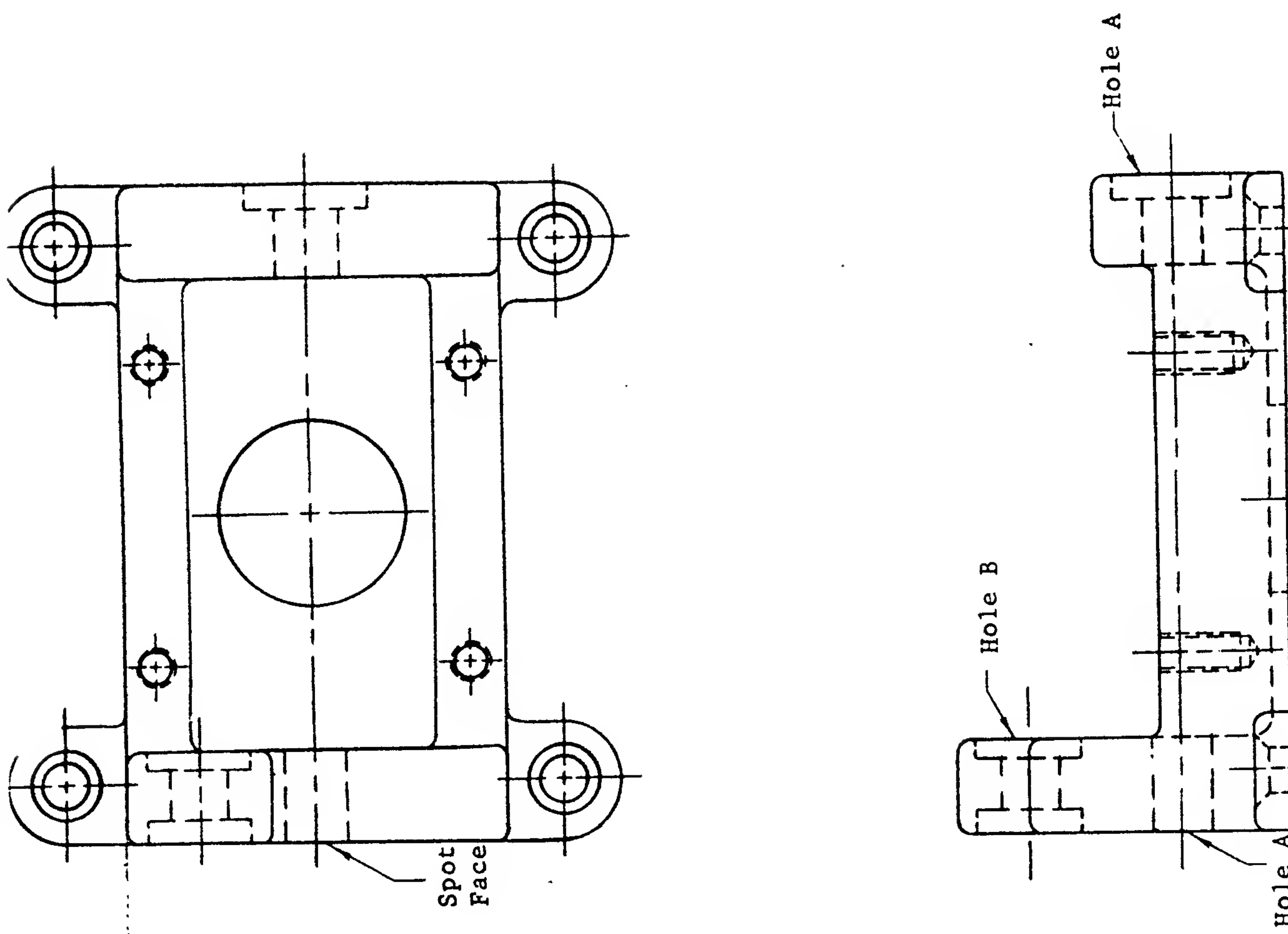
FIGURE XII

Combine Gear Box

Scale - half size



Note: Alter for spline shaft



Tolerance ± .001"

BOURN AND FREETH LTD.

This company was a well established firm that specialized in the manufacture of precision machine tools. Over a period of years they had created an excellent reputation for accuracy in the work done by their tools.

At present they were producing two precision jig borers for a company doing defense research work. The final accuracy of the machine had been guaranteed to be 0.0001". This meant that most parts in the machine had to be made to at least this tolerance. Even the least important of drive gear teeth had to meet a tolerance of 0.0005".

Mr. Howard, a recent engineering graduate, had just joined the company's production department. His first job was to schedule the manufacture of four auxiliary drive pinion shafts for the jig borer. He had to arrange for time on the various machines that would be required to make this part.

This particular part was made of steel and consisted of a pinion on a hollow shaft, the whole unit being machined from one piece of stock. Both the shaft and pinion were hardened after machining. The pinion was a helical gear. It had 22 teeth and a helix angle of 23 degrees which gives a diametral pitch of 11. The shaft was 1 1/2" in diameter and had a hole through it and the pinion 1" in diameter. The face width of the pinion was 3/4" and the overall length of the unit was 3 1/4". Close tolerances were specified on all these dimensions with the exception of the width of the pinion.

Bourn and Freeth manufactured all their own gears. They also did all the necessary machining operations required on any of their machines. Their gear shop was the most completely equipped with gear making machines in Canada. Besides having a complete stock of formed tooth cutters for milling machines and broaches, they also had several Fellows gear shapers, a Sykes gear generator, and several hobbing machines. In addition, they had all the necessary machines for gear finishing operations.

The B. and F. grinding department was equally well equipped. It contained the usual cylindrical grinders including some centreless grinders. There was also an assortment of internal, surface and tool grinders in the Department.

QUESTION

What are the various operations on this pinion shaft and on what machines should they be done?

TAYLOR ELECTRICAL COMPANY

The Taylor Electrical Company manufactured small electric motors. Most of its output was of standard design. Parts were manufactured and assembled, and the finished parts placed in stock. Shipments were made from this finished goods inventory.

One of the most successful numbers in the company's line was a small induction motor used in electrical phonographs. During the years 1948 to 1952 sales of these motors had averaged 8,000 per year, although sales had fallen off in 1951 and 1952. Company engineers believed that a redesigning of the mechanism was necessary.

The redesigned phonograph motor required a new base plate. The designing department and production manager decided that 150 of these should be made since two experimental ones had proven satisfactory. It was expected that 8,000 would be required the first year. This volume would be made in four lots of 2,000 each.

There were three methods by which the initial lot of 150 base plates could be made. They could be made from sheet steel by hand. Each base would take an hour to make and would require a skilled workman at a rate of $1.80 an hour. Alternatively, the plates could be stamped out on a press using standard blanking dies and then finished by hand, or they could be stamped out complete on a press using permanent dies.

If blanking dies were used, the cost of the dies would be $80. However, these could be used for jobs at another time. It would cost $1.50 an hour for labour to operate the punch press making 15 plates an hour. There would be an additional labour cost of $1.00 each for finishing the stamped blanks.

Should the new design prove satisfactory, these blanking dies could be reworked at a cost of $175 to make permanent dies. The life of blanking dies would be the same as permanent dies, that is, about 100,000 pieces.

The third possibility was to make permanent dies to begin with and stamp the plates out complete in one press operation. If this was done, the dies would cost $250. The production rate would be 12 complete plates an hour using unskilled labour at $1.15/hour.

QUESTION

How would the base plates be made by each method and which method should the production manager adopt for the trial order?

STEEL FABRICATORS LTD

This firm had a large steel fabricating and erection business. It had originated as a custom builder of bridges and other structural designs. Over a period of years they expanded to the point where such work was being done on a production line basis. Machine shops, welding facilities and a steel foundry had been added.

The firm could now do any type of machining or cutting of steel. They could shear to any size. Steel plate could be rolled in lengths up to 12 feet and thicknesses up to 1/4". Cylinders could be rolled from 6" in diameter up, tapering them if the design called for it. The welding shop was most versatile. It could flame cut, arc or oxyacetylene weld, submerge arc weld, and do electrical seam or spot welding. The foundry, in addition to being able to cast steel or iron in a single pour up to 5 tons, was also capable of centrifugal casting long tubular sections.

The engineering department had recently heard that the local university was going to modernize its campus street lighting. They would need 300 new light standards. Steel Fabricators hoped to design and produce a standard that would economically allow them to enter this highly competitive field. Equally important as low cost would be appearance, strength, ability to withstand impact, long life and ease of erection.

Presently competing light standards are 25 feet long. Costs for various designs are given below. N.E.M.A. standards require that a light pole support a 500 pound load applied to the long axis, a load of 150 pounds on a horizontal 6 foot arm at the top with a deflection of no more than 5% in the 6 foot arm, and withstand a 250 pound load at the end of the six foot arm without collapse.

TABLE I

Cost of light standards - by types

Suggested Selling Price		Sections No.	Sections Length	Diameter Butt	Diameter Top	Wall Thickness
$76	Reinforced concrete	1	25'	14"	8"	2-4"
$85	Pre-stressed concrete	1	25'	12"	8"	2-4"
$78	Cast iron (spun)	1	12"	8"	4"	3/8"
$71	Steel (16 gauge sheet rolled and joined)	4	6 1/2'	10 1/2"	3"	.06"
$70	Steel (extra heavy pipe, 5", 4", 3" and 2 1/2" cut and welded)	4	9',7', 7', 5'	5 1/2"	2 7/8"	.326" (av.)
$75	Wood	1	25'	14"	-	solid

Designs of all these types were proposed by engineers of Steel Fabricators Ltd. The reinforced concrete design was to be spun and would contain three 1/2" diameter reinforcing bars. Its appearance would be enhanced by varying the cross-sectional shape. The pre-stressed concrete standard would have four 3/8" diameter steel bars. The spun iron design could also be produced with varying section shapes at no extra cost, but was proposed as a simple tapered cylinder. The sheet steel standard was also a simple tapered cylinder. The sheet was sheared, rolled to a taper, and then joined. Erection in the field was accomplished by merely sliding the sections together until they wedged securely in place. The steel pipe standards were made by cutting the pipe to length, sliding them together with a 12" overlap and welding them in place.

TABLE II

Physical Properties of Various Materials

Material	Specific Weight	Ultimate Strength	
		Tension	Compression
	lbs./ft^3	lbs./in^2	lbs./in^2
Reinforced Concrete	145	120	500
Cast Iron (Spun)	460	25,000	45,000
Steel	490	60,000	60,000
Wood	40	1,000	900

TABLE III

Relative Cost of Steel Joints

	Cost/ft
Bolts and Tapping plate (4)	25 cents
Nuts and bolts (4)	15 cents
Gas welding	42 cents
Arc welding	10 cents
Submerged arc welding	13 cents
Seam welding	12 cents
Spot welding (2" centers)	4 cents

Problem

Prepare a report comparing the product made by the various processes and describe all the processes involved in manufacturing the design you recommend.

TABLE IV

Other Process and Material Costs

Flame cutting	5 cents/ft
Shearing	15 cents/cut
Sheet rolling	$4.00 each
Centrifugal casting	29 cents/lb
Steel - sheet and bar	11 cents/lb
Concrete (poured)	$2.25/cu.ft.
Pipe	15 cents/lb

CHASE CLOCK COMPANY

This company was one of the largest Canadian manufacturers of electric clocks. In 1948, they developed a new design for an electric alarm clock. Instead of having the hands and dial in a vertical plane, the new clock would have the dial set in horizontally with numbers appearing on the half inch high edge of the dial. The numbers would rotate past a window 1/2" high x 2" long on the front face of the clock. Another new feature of the clock was that in three other smaller windows under the time window would appear the day, month, and date. All writing and numbers appearing in the various windows would be automatically changed electrically.

Since this was such a radical change, the designer set out to make a suitable housing for the clock. Finally, the alternate methods of manufacture had been reduced to die casting or plastic molding. The engineering department was then asked to prepare an estimate for making the clock housing by either method.

Overall dimensions of the housing were approximately 5 1/2" in diameter x 5 1/2" high. Average section thickness was 1/16". For die casting in zinc alloy, the total cost of die and tools for flash removal was $960. The cost of material for casting in lots of 25,000 was 14 cents each, without any applied finish. Chromium plating and buffing the casting would cost another 30 cents each. The part would weigh 14 oz. and would be produced at the rate of 165 an hour. The single cavity die required three weeks to be completed.

Assuming that the same piece be made in urea plastic, a single cavity mold would cost $1,825. It would take five weeks to make this mold. Material on the basis of a lot size of 25,000 would cost 23 cents per part. A molding rate of 20 pieces per hour was the shortest possible cycle. Even then it was doubtful if such a rate could be maintained over a long run.

QUESTION

What process should be used to make this clock housing?

EXHIBIT I

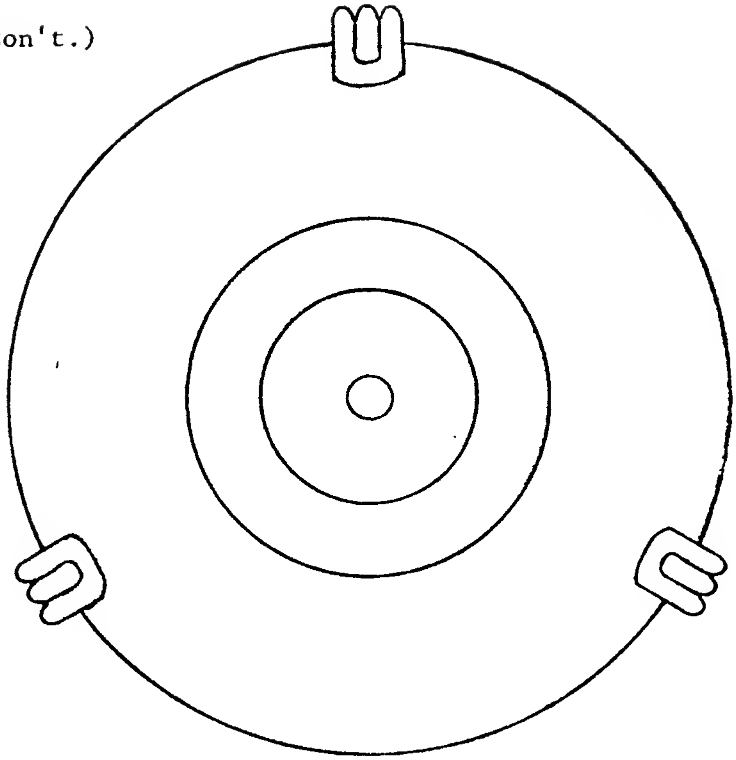
Comparison of Physical Properties

	Zinc Alloy	Urea Plastic
Specific gravity	6.6	1.5
Tensile strength	45,000 psi	10,000 psi
Compressive strength	74,000 psi	27,000 psi
Impact strength		
Izod 1/2" x 1" bar		0.5 ft. lb
Charpy 1/4" x 1/4" bar	36 ft lb	
Tolerances	± .001 in	± .005 in.

Total machine costs = $5.00/hr for die casting
= $3.05/hr for plastic press

Painting (if used) = 7 cents/part - 3 coats spray paint

CHASE CLOCK (Con't.)



CHASE CLOCK

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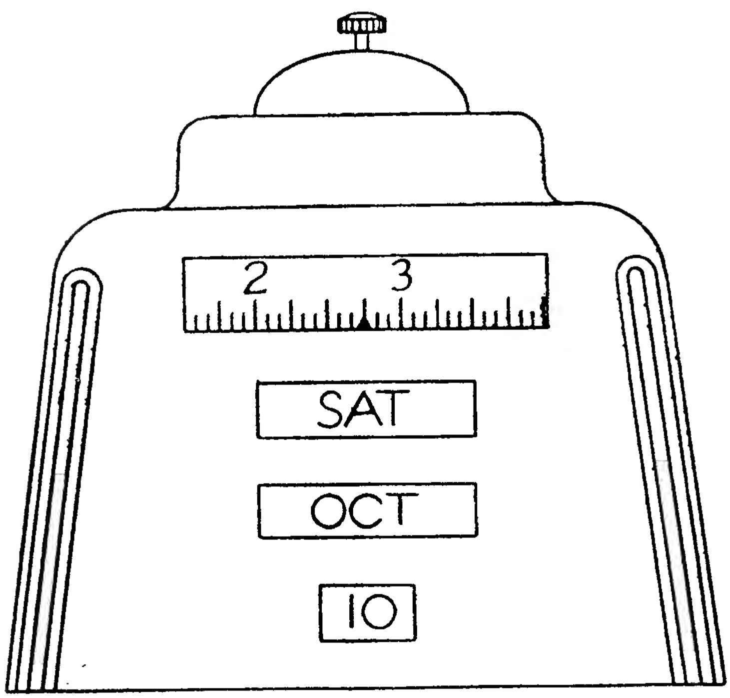

BRAUN STEEL COMPANY

About 1953, a German company, Braun Steel, became interested in setting up a mill in Canada. They were aware that both Eastern Canada and the U.S. had an extensive and well diversified steel industry. However, there was little in the west by comparison. They therefore focused their attention on that area.

The company discovered that there was a small rolling mill in Manitoba. Another one, whose production was 30,000 tons per year, had recently started operating in Vancouver. Both these mills utilized local scrap steel to provide only light bar, rod and structural steel shapes for the surrounding area.

No iron ore was smelted in the west. Any supplies of pig iron were brought from Algoma Steel at Sault Ste. Marie, Ontario. Production of scrap iron and steel in 1952 amounted to about 70,000 tons in B.C. About 45% was not consumed locally and was exported to Japan and the U.S. In Alberta there were about 55,000 tons of scrap iron and steel produced in the same year. Only 10,000 tons of this was used in the province.

Figures were available to Braun Steel to show that the steelmill in Vancouver was supplying all of the needs of B.C. for light rolled sections. The rolling mill in Selkirk, Manitoba, was similarly serving the area around it and west to the rockies.

Directors of Braun Steel wondered if they could successfully compete with the B.C. and Manitoba steel mills, if they set up a mill in Alberta. In 1951, the rolling mill products shown in Exhibit I were brought into Alberta. The sheet and plate averaged about 4 1/2 cents/lb. and the structural steel cost was around 8 1/2 cents/lb.

EXHIBIT I

Rolling Mill Products Brought into Alberta in 1951

Bar and rods	5,900 tons
Plate	8,400 tons
Sheet	4,800 tons
Structural shapes (light)	13,000 tons
Structural shapes (medium)	5,900 tons
TOTAL	38,000 tons

BRAUN STTEL (Con't)

It was also thought that with the developing oil and natural gas industry in Alberta, a ready market for pipe should be available. A pipe mill of 6,000 tons per month capacity could be set up for about $5 million. This would be capable of producing only one type of pipe. If it was desired to use more than one process for making pipe, each additional type produced would require a capital outlay of one-half million dollars.

Exhibit II shows the purchases of pipe in Alberta for 1951. The average cost per pound was 11 cents. The distribution of pipe purchases by size is shown in Exhibit III.

QUESTION

If Braun Steel Co. set up a mill in Alberta, should they produce rolled sections of pipe of one of the types below?

- Lap welded
- Butt welded
- Electrical resistance welded
- Seamless
- Extruded
- Cast

EXHIBIT II

Purchases of Iron and Steel Pipe in Alberta - 1951

Pipes cast	$8,000
Pipes and Tubes wrought - steam lines	67,400
Pipes and Tubes wrought - under 2 1/2"	9,000
Pipes and Tubes seamless	15,000
Pipes and Tubes - over 10"	40,000
Pipes and Tubes - under 10"	1,220,200
Tubing, coated - under 1/2 inch	3,700
Pipes and Tubes wrought	190,000
Pipes and Tubes seamless - under 1"	2,600
Steel pipe for casing water, natural gas, or oil wells	12,549,000

Source: Dominion Bureau of Statistics

EXHIBIT III

Tube and Pipe Sales by Size

1/4 inch	0.5%	2 1/2 inch	4.3%
3/8 inch	0.6%	3 inch	7.4%
1/2 inch	3.7%	3 1/2 inch	1.0%
3/4 inch	6.8%	4 inch	8.7%
1 inch	9.9%	5 inch	3.1%
1 1/4 inch	9.4%	6 inch	12.4%
1 1/2 inch	7.4%	8 inch	5.6%
2 inch	12.4%	10 inch	4.3%
12 inch (and over)	2.5%		

LAMSON AND SESSIONS COMPANY

The Lamson and Sessions Company was a prominent manufacturer of machine and carriage bolts, nuts, rivets, cotters and wire rope clips. The company was considering the adoption of a new type bolt to replace the standard carriage bolt (see Figure 1). This new bolt was designed primarily for the needs of the automotive industries, but it could be used in others as well.

The design of the common carriage bolt was the result of haphazard development rather than of scientific research. Originally, it had been hand-forged from square bar stock. It was a round-headed bolt with a square shoulder to prevent rotation. Early bolts had shoulders that extended almost to the end of the bolt, with a very short threaded section. Often, the thread was cast on the square material with little attempt to round the section to be threaded.

The long shoulder ceased to exist with the introduction of automatic bolt machinery. It was unnecessary and in addition it was hard to make. The raw material was changed to round stock and the problem then became one of producing a square shoulder rather than rounding the threaded end of the bolt.

Carriage bolts had been standardized in 1920. The head of the carriage bolt was, in the opinion of Lamson and Sessions engineers, two and three-fourths times as high as was needed. The sole requirement of the head was that it would not shear through under tension. Comparison of the carriage bolt with other similar bolts also indicated that the head of the carriage bolt was larger than necessary.

The designers of Lamson and Sessions Co. had produced a new bolt which they felt would give as good service as the carriage bolt (see Figure II). It was believed that this new type with its diamond shoulder would eliminate certain difficulties common to the manufacture of square-shoulder carriage bolts. The proponents of the new bolt also pointed out that this was a means of combating increasing competition. From the consumer view point there were advantages to the new bolt. In the automotive industry carriage bolts were used in the wheels of automobiles. But under the strain of vibration in operation the plate in which the square holes for the bolt shoulders were punched often cracked and broke. The new bolt, it was felt, would prevent this by eliminating the stress concentrations in the corners of the holes in the hub plates.

With the old type of shoulder, dirt from the raw materials became imbedded in the square corners of forming dies. This dirt often accumulated in two hours of operation and resulted in bolts with corners insufficiently square to pass inspection. In order to remove the dirt, the tools had to be taken apart and cleaned. This entailed 15 to 30 minutes down time. It was felt that the new bolt with its rounded corners would eliminate this difficulty.

The shoulder dies for the new bolt would be easier to make than the square broached hole for the old design. Cracking in the corners of the dies due to stress concentration after hardening would also be avoided. There would therefore be fewer defective dies and the die life for the new bolt should be much longer.

QUESTION

How would the new carriage bolt be made and should the company produce it?

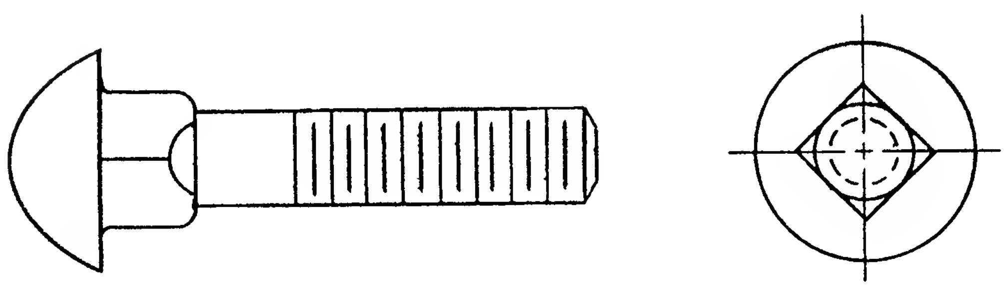

FIGURE I

Common Carriage Bolt

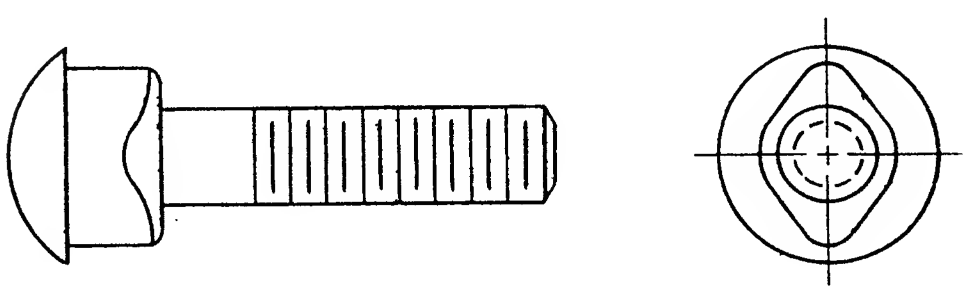

FIGURE II

New Diamond Shoulder
Carriage Bolt

MANTON CORPORATION

The general manager of Manton Corporation, Mr. Haines, called a general meeting of his designers, engineers, senior foremen and sales staff. He pointed out that since the company produced stampings and cold forgings solely for the automotive industry the recent strikes among automobile manufacturers had caused violent swings in Manton's production volume. For a while they would be working near capacity and then a strike would come and cut production to almost nothing.

This situation was severely taxing the company's finances. The previous year the company was just able to break even on the cost of its operations due to one strike. That was now settled but another strike appeared imminent. Mr. Haines stated that if Manton Corp. had to carry its key personnel on salary over another long strike and again lose all its trained machine operators when they were laid off, that it would be difficult for the company to regain its competitive position. This would jeopardize everyone's jobs. Therefore it was essential to diversify the company's production.

The sales manager had just returned that morning from Ottawa. He got up and said that Mr. Haines and the rest of the group would be pleased to hear that something was already accomplished in this respect. He had learned that a company had just defaulted on a defense contract and consequently gone broke. They had been making the small gear segment shown in Figure I by machining a bronze casting. However, they had been unable to make the narrow slot 0.020" wide to the desired tolerances, nor had the machined gear teeth satisfactorily stood up to wear tests.

By intimating that Manton could forge the parts and do a better job for the same price the sales manager had come home with a tentative contract for 35,000 of the parts. If this order was satisfactorily completed, others for different parts would be made available to the company. Mr. Haines was delighted. The technical people complained that the sales manager had gone out on a limb because you could neither machine nor forge the 0.020" slot to the required tolerances. Mr. Haines replied that without the slot Manton would not get the order, so they had better find a way to make it.

The meeting ended at this point. The foremen and many of the others went to see how they could forge the part and to determine the cost. One engineer, however, had an idea that this part could be made by powder metallurgy. He set out to investigate this possibility and drew up the table shown in Exhibit I.

QUESTION

Could Manton produce this part most economically by forging or powder metallurgy?

EXHIBIT I

Estimated Comparison of Production Methods

	Sand Cast.	Forged	Powder Compact
Material cost/lb	$.28	$.28	$.37
Specific Gravity of part	8.1	8.3	6.0
Tensile strength, psi	30,000	40,000	13,000
Pressure required, psi	---	45,000	25,000
*Machining time, mins.	35 ea.	---	---
*Production rate/min			
blanking		10	
compacting			6
coining		4	
Cost of dies			
blanking		$280	
compacting			$975
coining		$815	
Scrap	26%	14%	

*Note all machine costs the same at $5/hour.

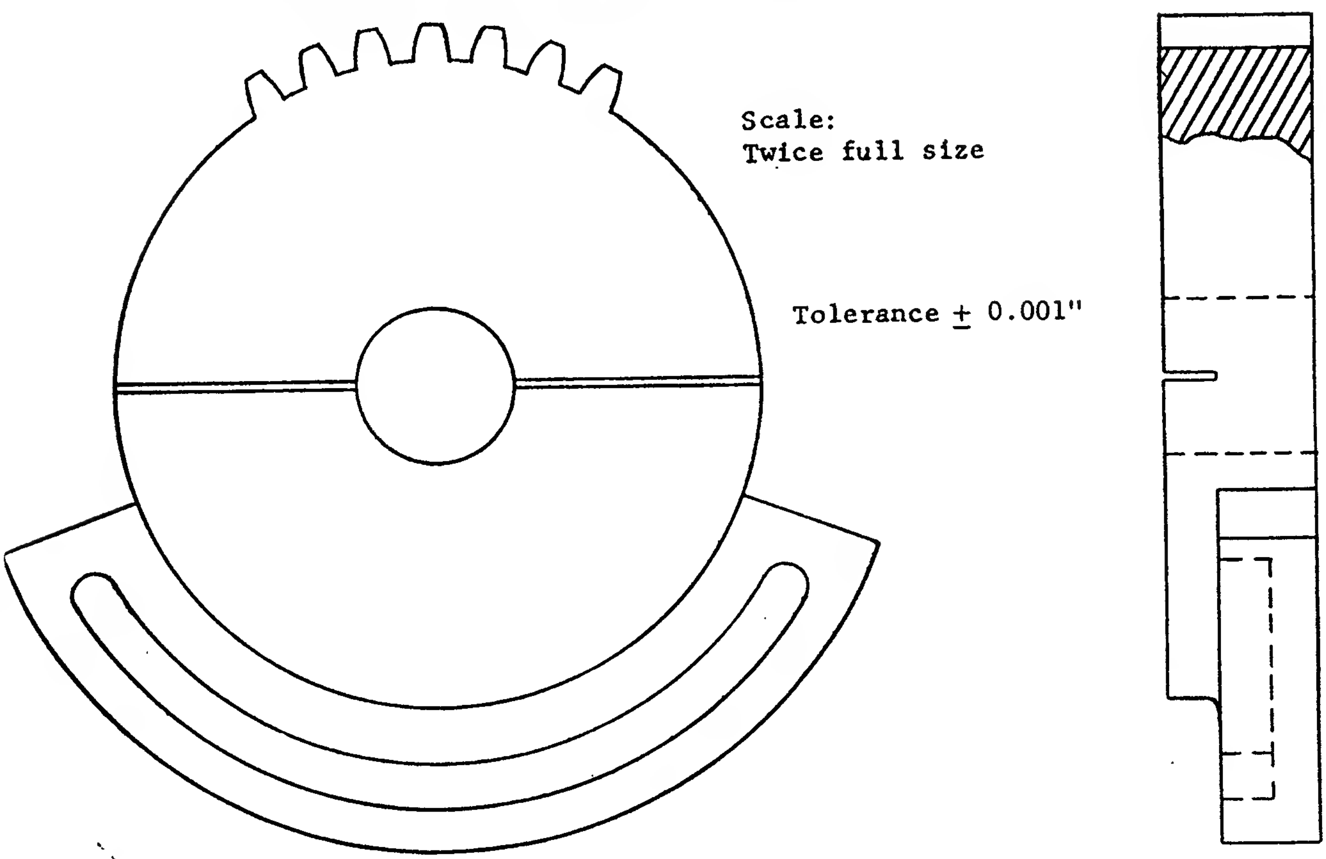

FIGURE IX
Bronze Gear Segment
Weight 0.3 lbs. (cast)

CANADIAN CABLE LTD.

Canadian Cable Ltd. was one of the largest Canadian producers of wire rope of all sizes. They also specialized in the manufacture of lead covered telephone cables.

Telephone cables were made up of anywhere from 20 to 760 pairs of wires. Individual wires were distinguished by colored coverings. Either a solid color or several colors in a striped pattern was used. Bundles of 20 pairs of wires were made by binding the group of wires with a cotton cord. Thus any cable was usually made in multiples of 20 pairs of wires.

The telephone wire was manufactured in the usual wire drawing machine. At the end of this operation, the wire passed through a rotating head that had two spools of colored paper mounted on it. The paper ran freely off the spools and provided the tightly wound colored covering for the wire.

When the company first began making this colored paper wrapping they had great difficulty turning out a satisfactory product. It was not until they discovered that the paper needed moisture content of 20% that the operation became successful. But this created maintenance problems.

After the paper came off the spools it passed over a guide roll before being wrapped around the wire. These rolls were originally machined out of cold rolled steel. But even though they were free to rotate they wore very rapidly. The paper would cut grooves in the rolls which, when deep enough, would catch the paper and break it. When the paper was run dry, it had merely been a problem of frequently replacing the worn rolls. But with the moist paper rust also became a problem.

Furthermore, particles of rust and steel would adhere to the moist paper and cause the dielectric property of the thin sheet to be destroyed at such points.

The company had 30 wire drawing machines with the paper wrapping attachment. Each unit had two flanged guide rolls 1 1/2" in diameter x 3" long, with a fixed axle on each end 1/4" in. diameter extending 1" out from the roll.

QUESTION

How could the rust and wear problem be eliminated on the guide rolls of the paper wrapping attachment?

EXHIBIT I

Plating Costs for Guide Rolls

Chromium	-- .001" "hard"	$2.80 each
	-- "decorative"	1.50 "
Cadmium	-- .0005"	.20 "
Zinc	-- hot dipped	.15 "
Nickel	-- .0005"	.30 "
Buffing (extra)		.70 "

EXHIBIT II

Cost of Various Materials

Machining cost for guide roll	55 cents each
Stainless steel (type 316)	95 cents/lb.
Nickel alloy (SAE 2315)	16 cents/lb.
High speed steel (SAE 1841)	$1.41/lb.
Metal spraying guide roll -	
Stainless Steel	$4.75 each
Zinc	4.50 each
Aluminum	4.50 each